HSER 4358

MAN-SYSTEM TASK ANALYSIS PROGRAM

FINAL REPORT

ERECTION AND DEPLOYMENT OF OPTICAL ASTRONOMY PACKAGE

21 DECEMBER 1966

PREPARED FOR:
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
CONTRACT NUMBER: NAS 8-20095, MODIFICATION 2
REQUEST NUMBER: 1-5-56-01257

Hamilton Standard
WINDSOR LOCKS • CONNECTICUT
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1.0 INTRODUCTION

A contract was awarded to Hamilton Standard to provide the technical direction and program management for an experimental investigation which would develop design criteria for lunar scientific equipment and the pressure-suited energy requirements to operate this equipment. The test experiments were conducted in the Task Analysis Facility (TAF) at the George C. Marshall Space Flight Center (MSFC), Huntsville, Alabama.

The lunar scientific equipment mockup selected for use in phase II of this program was the Optical Astronomy Package (OAP), which was mounted on the top of a simulated LM shelter. The tasks involved in the test effort were the erection and deployment of the OAP.

2.0 OBJECTIVES

The objectives of the phase II test program were accomplished. These objectives were:

1. To provide a task-oriented timeline analysis for the OAP erection and deployment
2. To establish human engineering design criteria and general human factors constraints for the tasks involved in the OAP sequences
3. To prepare the human factors portions of the final phase II report
4. To provide a photographic record of the test sequences
5. To establish energy and time requirements for the OAP erection and deployment tasks and subtasks
6. To prepare the metabolic cost portion of the final phase II report

No attempt was made to verify the estimated time required to complete the entire OAP mission. The total mission time estimates and those portions of the task timeline sequence not connected with the erection and deployment sequences were included in this report for information purposes only.

In addition to the above, a complete baseline calibration, both in shirt sleeves and in a pressure suit at 3.7 psig, was conducted on each of the three test subjects. The baseline calibration was used to correlate metabolic rate with walking speed, heart rate, respiration rate, and deep body temperature.

3.0 SUMMARY AND CONCLUSIONS

The OAP mockup was judged adequate, with respect to accomplishing the objective of erection and deployment of the equipment. The major human performance deficiencies were in the areas of safety provisions and accessibility.

Little or no design emphasis was placed upon the incorporation of effective safety devices such as hand holds, rails, and barriers. The fact that the work areas were elevated should dictate the incorporation of the maximum practical safety features.

Accessibility of the equipment was quite restricted in both the storage and deployed modes. Excessive horizontal and vertical reach requirements were exhibited throughout the task. In addition, movement about the OAP mockup was quite difficult and, subsequently, hazardous due to insufficient walking space.

The OAP mockup was also deficient in crew maintainability features. In terms of flight hardware, this shortcoming could result in a mission abort. Accessibility for repair or replacement of such items as terminal boxes, fuses, drive motors, and electrical connections should be of major consideration in the design of the OAP and the support equipment. The OAP mockup lacked several important functional features such as equipment tiedowns and telescope/yoke and yoke/LM shelter electrical and mechanical connections. The incorporation of the tasks connected with these items (which are included in the timeline analysis) could significantly increase the time required to complete the erection and deployment sequences.

The complete discussion of the OAP mockup features, along with specific recommendations for design improvements, is contained in paragraph 6.3.

The energy and time requirements for the OAP erection and deployment task sequence were determined to be:

1. Position A (work station-top of LM shelter), average metabolic rate 947 Btu/hr with an average task time of 26.1 minutes

2. Position B (work station-base of LM shelter), average metabolic rate of 1008 Btu/hr with an average task time of 24.8 minutes.

These positions are identified in figure 3. The average total energy expenditure for this task was, therefore, 412 Btu for Position A and 416 Btu for Position B. The total pressurized suit time logged for this phase of the test program was 176.3 hours.

The accuracy of the metabolic rates determined, to one standard deviation, was $\pm$ 4.9 The metabolic rate data contained in this report have been presented as calculated; however, due to the variations in human performance and the instrumentation inaccuracies, the last two digits of these numbers are not significant.

3.0 (Continued)

It was observed that the heart rate could be used to predict metabolic rate with a total error band of 400 Btu/hr or less, dependent upon the test subject involved. In order to successfully employ this technique, the test subject must be working at a stabilized rate and be in excellent physical condition. In addition, the curve of heart rate versus metabolic rate for the pressure-suited mode must be developed using one well-fitting pressure suit for each subject. The metabolic cost (emcumbrance) to the test subject of wearing the A-4H-035 Apollo Training Suit varied from 730 to 1305 Btu/hr at 2.0 mph for the three test subjects involved in the program.

4.0 RECOMMENDATIONS

4.1 Recommendation 1

A nitrogen analyzer should be added to the gas analysis system in the Task Analysis Facility. This instrument will provide verification of the oxygen and carbon dioxide percentages, and will reduce the possibility of errors in the gas analysis.

4.2 Recommendation 2

The group of test subjects available for work on this program should be increased to four, inasmuch as three subjects are necessary in each experiment. The complete qualification of a test subject (physical conditioning and suit/task familiarization) involves a time period of at least two to three months. "Last minute" changes are prohibitive.

4.3 Recommendation 3

The preliminary work on the relationship of heart rate to metabolic rate shows some promise as an "order of magnitude" technique for predicting energy cost of various activities. A distinct effort should be initiated toward more accurately determining the limitations and variations of this method. A great deal of statistical data must be developed before a level-of-confidence factor can be determined.

4.4 Recommendation 4

A second generation of OAP hardware should be provided to repeat these tasks. This second generation should incorporate design criteria generated as a result of this study and be specifically oriented to pressure suit constraints. In order to reduce hazards associated with elevated work areas, design effort relative to crew safety and maintenance accessibility should be emphasized. In addition, the second generation mockup should include all required functional equipment in order to more accurately determine mission time requirements.

4.5 Recommendation 5

The only psychophysiological stresses and environmental constraints which were imposed during the mission simulations are those associated with a pressure-suited crewman functioning in a one g, 3.7 psig environment. At the present time, there are no possible, direct quantitative correlations between mission parameter simulations as are accomplished in the TAF and the actual condition which can be expected during a lunar mission. The next logical step in mission profile simulation would be to incorporate the more realistic psychophysiological stresses of 1/6-g, temperature, tilt angles of the LM shelter, lighting, and current Apollo pressure suits.

5.0 TEST PROGRAM

5.1 Time Line Analysis

The basic test plan for this phase of the Man-System Task Analysis program consisted of a task-oriented timeline sequence which presented, step-by-step, the specific tasks to be accomplished by the Apollo crew members during the erection and deployment of the OAP functional mockup.

Wherever feasible, an attempt was made to incorporate overall Apollo mission constraints and criteria during the simulations. However, time duration for personnel subsystem operation was not contrained because it was assumed that future generation subsystems would have sufficient capacity to perform the entire OAP mission.

To adapt the basic test format to the physical limitations of the Task Analysis Facility and the OAP functional mockup, the tasks presented in sequence blocks 123 through 408 formed the mission profile, except that the LM ingress and egress sequences and the mechanical and electrical connector interfaces were not part of the test simulations. The complete timeline sequence is presented in appendix A of this report.

One of the most critical parameters to be considered in establishing and evaluating the various Apollo applications missions will be that of the time versus task requirements for a pressure-suited crew member to accomplish mission objectives. It is for this reason that the following "drawing board" figures have been incorporated as overall mission time requirements for the OAP erection and deployment tasks:

Don Apollo Pressure Garment Assembly (PGA)	15 min
Don PLSS and system check complete Apollo EMU assembly	90 min
Depressurize LM	6 min
Pressure LM	6 min
Open or close LM external hatches	3 min
Ingress or egress LM	5 min
Ascent or descent LM exterior	5 min
Assemble and erect work platform	15 min
Unstow and erect derrick	30 min
Unstow, hoist, and position yoke assembly	60 min

5.1 (Continued)

Unstow, hoist, and position telescope assembly	60 min
Accomplish external OAP mechanical and electrical connectors	20 min
Accomplish internal OAP mechanical and electrical connectors	20 min
Gross position OAP assembly	15 min

Using these "drawing boards" figures, the total mission time required to complete the mission objectives, sequence blocks 1 through 435, would be 454 min (approximately 7.57 hours).

These time versus task parameters represent a "best estimation" for an optimum mission profile in terms of the specific functional tasks required of the crew members.

The operational functions, control functions, evaluations, and decisions associated with the optimum profile were identified. An attempt was made to establish realistic time estimations considering applicable mission constraints and, where possible, the psychophysiological stress of the mission environment.

5.2 Test Subjects

Three test subjects were involved in the test program. Two of the men were provided by MSFC/NASA and the third was the Hamilton Standard Resident Engineer. The men were volunteers, with a major requirement being physical size in order to properly fit the Model A4H and HECMAR pressure suits that were available for the program. The three men ranged in age from 24 to 40 years, in height from 170 cm (67 inches) to 175.5 cm (69 inches), and in weight from 65.7 kilograms (145 pounds) to 73.0 kilograms (161 pounds). Prior to final acceptance for the test program, the men were required to pass a rigorous physical examination which placed particular emphasis on their respiratory and cardiovascular systems.

5.2.1 Physical Conditioning

A physical conditioning program for the subjects was organized by Hamilton Standard during the phase I portion of the test program. The conditioning program was continued during this phase of the test program in order to maintain the high level of physical fitness and physical stability attained by the men.

The physical conditioning program included the 20-inch Harvard Step (step up a 20-inch step, stand erect, and step down; 30 repetitions per minute for five minutes), 5.2.1 (Continued)

a one-mile run, general calisthenics, and active sports (basketball, volleyball, etc.). The program was conducted daily during the work week for 60 to 90 minutes each day. Once a week, the Harvard Step Test was used to determine the relative stability of the test subjects. The test score was based on pulse recovery one minute after completion of the exercise. While it is recognized that this method does not represent a complete index of physical fitness, it does provide a gage of the man's physical fitness and stability when compared to his earlier scores.

The men were well qualified and completely familiar with the types of pressure suits used in the test program. Each man had approximately 30 hours of pressurized suit time prior to the initiation of this test phase.

5.3 Instrumentation and Equipment Systems

The instrumentation and equipment used in this program was GFE and was maintained by MSFC support groups.

5.3.1 Optical Astronomy Package (OAP) Mockup

The Optical Astronomy Package is the result of a program involving analyses of potential lunar surface astronomical investigations, conducted for NASA by the Kollsman Instrument Corporation, Syosset, New York. The OAP configuration is basically a telescope consisting of a modified Goddard Experiment Package (GEP), adapted to the Apollo Applications Program (AAP).

5.3.1.1 Major Components - The OAP mockup provided by NASA for this test phase consisted of the following major components:

Telescope and Yoke - These portions of the total OAP simulated the size and weight of the actual parts to be deployed in the lunar environment. The mockups weighed 1/6 of the estimated weight of the actual OAP parts and had realistically located centers of gravity. The mockup was capable of articulated movements (manually powered) to simulate the movements of the actual system. The telescope mockup had provisions for the insertion and/or removal of specific "black box" devices associated with different types of experiments.

Platform and Derrick - These parts of the OAP were constructed to operate under the stresses of earth weight. The platform was made to the correct physical dimensions and as light weight (not 1/6-earth weight) as was practical, without sacrificing the safety of the astronaut. The derrick was a stowable A-frame with a third articulated, extendable, power driven arm.

5.3.1.1 (Continued)

Major Component Size

Telescope	43" dia. x 9 1/2' long
Yoke	14" square box-type fork on 26" AZ ring
Derrick (deployed)	16', electrically positionable tripod with electric hoist
Work Platform	30" x 30" fixed section, plus a 22" x 30" fold-down extension

These components are shown in figure 1 in a stowed position on the LM shelter.

To provide realistic training in an earth environment, an automatic deployment approach was used. By operating a control box, the derrick was positioned and the telescope and yoke deployed. Safety limit switches were incorporated into the derrick and hoist systems to eliminate damage to the derrick and its supporting structure.

5.3.1.2 MSFC Mockups and Construction - A mockup of the upper area of the LM descent stage was constructed on the MSFC TAF floor. The mockup was essentially a platform 8 inches high, conforming to the actual length and width dimension of the proposed LM descent stage. The OAP supporting framework (built by Kollsman) was then assembled and secured to the platform. On top of the supporting framework, approximately 9.3 feet above the descent stage mockup, a safety platform was constructed. The platform utilized all of the available space between the A-frame derrick arms and the sides of the LM shelter adjacent to the arms. A mounting fixture for the astronaut work platform was built into the safety platform. The work platform was positioned into the fixture and permanently secured, as a safety measure.

A deployment area 77 by 63 inches, corresponding to the size of the LM shelter roof, was marked off on the safety platform with 1/4- by 1-inch strips. The strips could be felt by the suited test subject through his boots as he reached the extremities of the deployment area. The deployment area was painted white, and the remaining "safety area" of the platform painted black. (In actuality, the black area did not exist.) The color arrangement allowed the test subject to see his work area better and allowed a good contrast for the filming sequence. Four external yoke latches were bolted to the platform's white area to secure the mockup. Four guide fixtures were then mounted beside the yoke latches to provide alignment while positioning the yoke mockup.

Safety lines were installed on top of the LM shelter around the deployment area in which the suited subjects worked to prevent the subjects from falling to the ground.

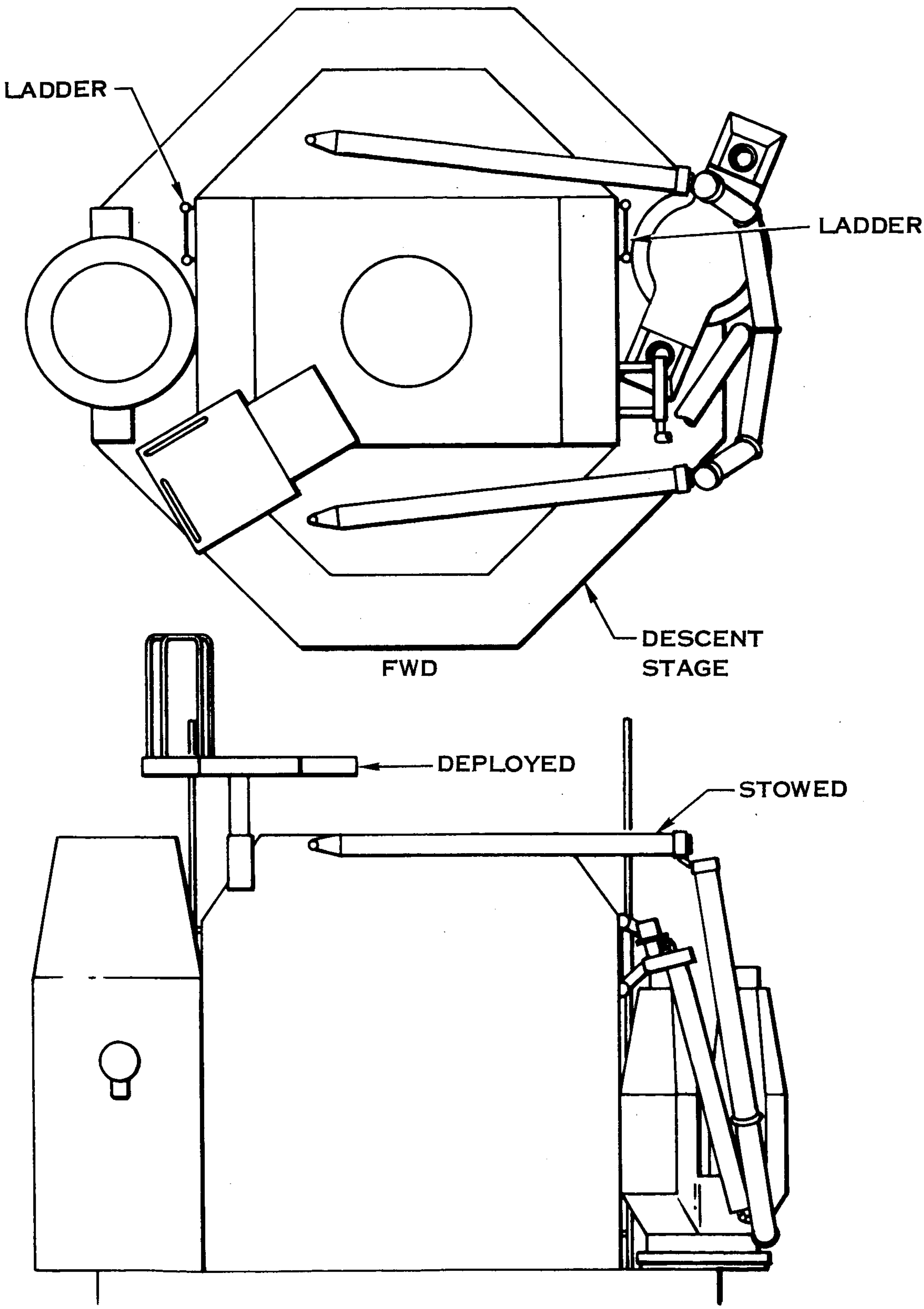


FIGURE 1. OAP MOCKUP IN STOWED POSITION

5.3.1.2 (Continued)

Two ladders with accompanying handrails were designed and built to provide access to the LM shelter safety platform. The ladders were constructed of 1.33 O.D. pipe, 20 inches wide with 11 inch rung centers. The handrails incorporated as assist handle at the top of each ladder to help the subject stabilize himself as he approached the top of the ladder. The ladders were attached vertically to the sides of the LM shelter and the handrails were attached near the top of the ladders. The ladders were designed for safe use by the test subjects, rather than for lunar mission requirements due to pressure suit constraints.

A LM shelter was constructed on the 8-inch high LM descent stage. The mockup enclosed the OAP support framework and extended vertically to the safety platform. The mockup provided a surface approximately 15.75 inches wide on the LM descent stage, allowing the subjects to walk around the LM shelter. The walking area represented the maximum available working space on the proposed LM.

The OAP mockup, as used, is shown in figure 2.

The major steps in the OAP deployment are illustrated in figure 3. A detailed procedure of the required OAP erection and deployment of the OAP is contained in the timeline analysis (appendix A).

5.3.2. Pressure Suit Assembly

5.3.2.1 Pressure Suit - The pressure suits utilized during this phase of the program were the Model A4H Apollo Training Suit and the HECMAR pressure suit. These suits were identical in concept, and were designed to provide durability and a wide range of adjustment in order to fit a variety of individuals. They were not completely representative of current Apollo designs or specifications; however, the A4H and the HECMAR suits were the only suits available to MSFC. The human engineering data and metabolic costs determined through the use of these suits will provide a satisfactory "safety factor" when applied to the design of current and future space systems.

5.3.2.2 Helmet - The helmets that fit the two suits were radically different. The HECMAR helmet was a head-restraining type, with a movable visor, similar to the Gemini helmet. This helmet held the head securely by means of webbing so that the helmet rotated in the neck ring when the head was turned. It did not readily lend itself to a mouthpiece system for respiratory gas collection, therefore, the HECMAR suit was used during the human factors data collection, but was not used to collect metabolic cost data. The A4H helmet was the Model C3, a fixed visor, non-head-restraining helmet which was similar to the design used in the Apollo program. This helmet remained in a fixed position in the neck ring, and the head was free to move within the helmet. Being readily adaptable to a mouthpiece system, all metabolic data was obtained using the A4H pressure suit.

FIGURE 2

LM SHELTER / OAP FUNCTIONAL MOCKUP

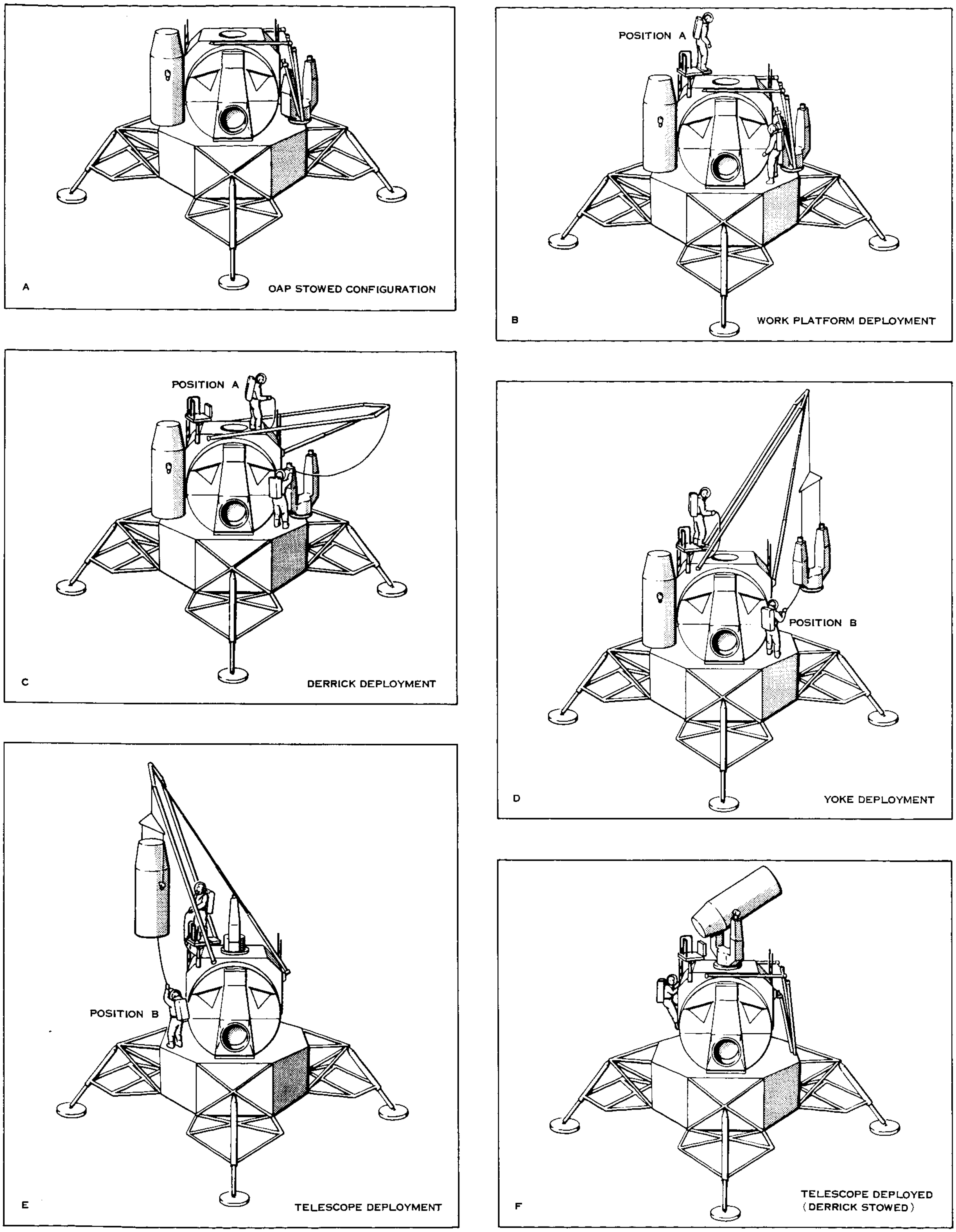


FIGURE 3. OAP DEPLOYMENT SEQUENCE

5.3.2.3 Liquid Cooling Garment - A Liquid Cooling Garment (LCG) was worn under the pressure suit to provide test subject cooling comfort. This garment contained a multitude of small plastic tubing in the torso and extremity areas. Cooling water was recirculated through the garment tubing at a flow and temperature which would maintain the wearer between the thresholds of sweating and shivering. In this manner, the major cooling of the subject was accomplished by sensible rather than latent means. The LCG used in this program was similar in concept to the Apollo garment.

5.3.3 Biomedical System

An FM telemetry system was utilized to provide biomedical monitoring of the test subject. This system consisted of (1) the biomedical sensors attached to the man, (2) the signal conditioners, battery and transmitter carried in the back pack mockup, and (3) the receiver with associated visual displays.

The biomedical data consisted of ECG wave forms, heart rate, deep body temperature, skin temperature, and respiration rate. These parameters were recorded on an oscillograph for analysis. Particular attention was directed to the heart rate, deep body temperature, and respiration rate as these parameters give an early warning of overwork or potential exhaustion. A digital readout of these key data was displayed in order to provide for rapid and continual surveillance by the test director.

5.3.4 Gas Analysis System

In order to obtain the metabolic rate of an individual, it was necessary to determine both his oxygen consumption rate and his carbon dioxide production rate. Toward this end, measurements were taken of the oxygen and carbon dioxide percentages in the inspired and expired air and the expired air volume per unit of time. The expired gas sample was obtained by requiring the test subject to exhale into a Douglas bag for a measured period of time. The system used to perform the analysis on this sample is shown in block diagram in figure 4.

The gas analysis system contained inlet positions for both the sample to be analyzed and certified calibration gases. The O_2 and CO_2 analyzers were calibrated daily during use, by means of these calibration gases which span the maximum and minimum range of the analyzer. The actual analysis sample was supplied to the analyzers by means of a one-liter syringe which was filled from the Douglas bag.

The oxygen analyzer was a Beckman Model F3 with a full scale range of 16 to 21% oxygen. The carbon dioxide analyzer was a Beckman Model 1R315 with a full scale range of 0 to 5% carbon dioxide. The flowmeter/regulator, throttling valve, and pressure gage were used to maintain flow and pressure within the gas analysis equipment at the same levels which existed during the calibration procedure. This is a necessity, because the analyzers are devices which measure partial pressure of the gas to be analyzed rather than a true percentage. Thus, the total pressure must be held constant.

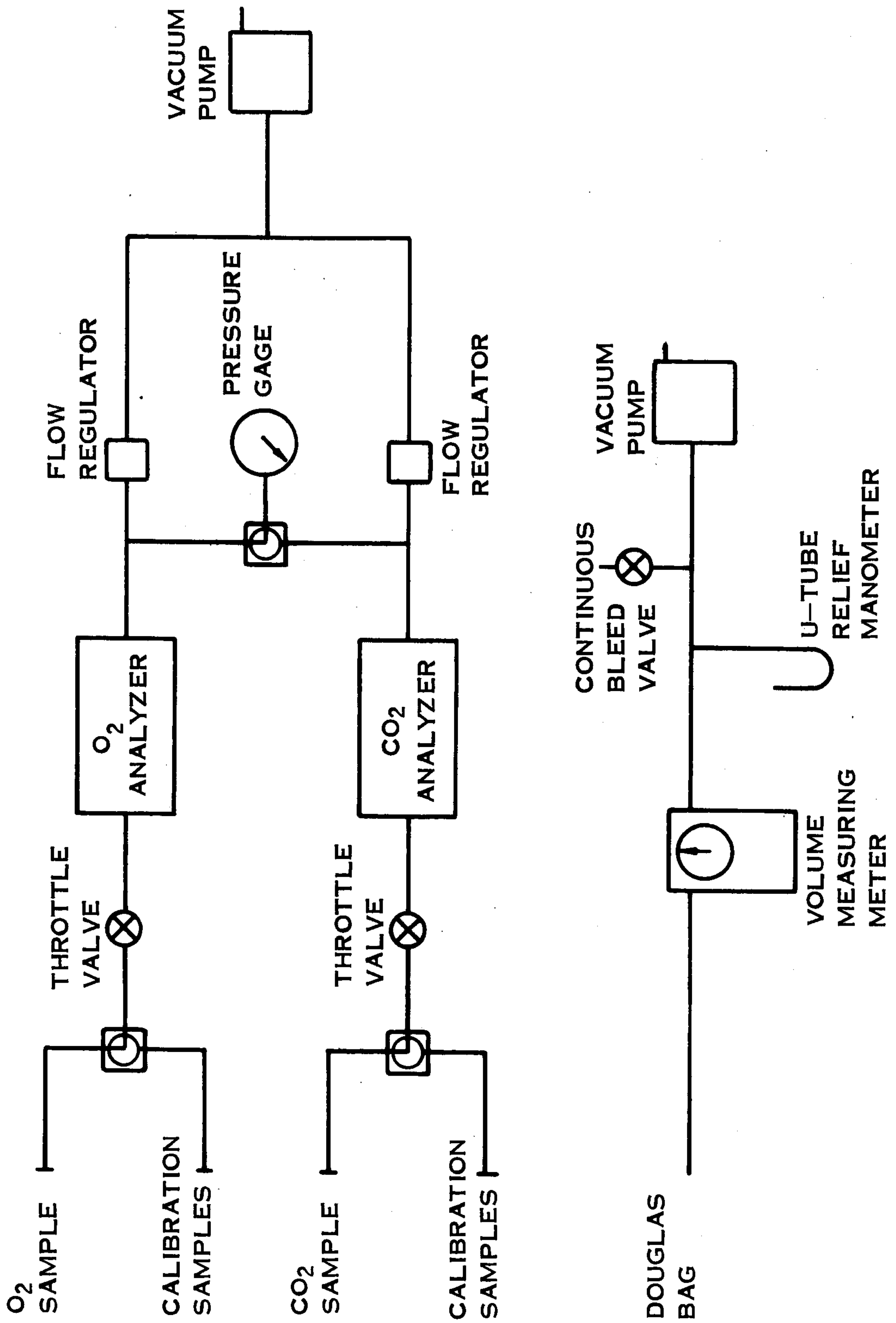


FIGURE 4. GAS ANALYSIS SYSTEM BLOCK DIAGRAM

5.3.4 (Continued)

The volume of the exhaled gas sample was determined by means of a dry gas meter, American Meter Company Model 802. The gas samples were drawn through the dry gas meter by means of a vacuum pump. The bleed valve was pre-set to provide a maximum blanked-off vacuum level which would not cause internal damage to the meter (6-inches H_2O below atmospheric pressure).

The U-tube manometer provided the pressure readout for the volume measuring system and, in addition, served as a vacuum relief in the event that the pre-set blanked-off vacuum level was exceeded.

5.3.5 Environmental Control System

5.3.5.1 Suit Pressurization - The Task Analysis Facility (TAF) was serviced with missile grade air at a nominal pressure of 3300 psig and a dew point of -70°, or lower. A pneumatic system was constructed, with this supply as the source, which provided suit pressurization and breathing air within the Apollo suit specification limits. The system was capable of maintaining two pressure suits at 3.7 psig ±.2 psig with combined flow rates to 20 cfm. The system exhausted to the atmosphere from the suit outlet. Flow control through the suit was provided by a flow control valve on the suit outlet umbilical. Inlet and outlet umbilicals were routed through a life support back pack mockup.

Suit pressure was servo controlled by sensing helmet pressure. If two pressure suits were in simultaneous use, the servo system was connected to the suit being used to collect metabolic data. Thus, the servo system controlled both suits within the pressure tolerance, but provided a greater degree of control to the more critical application.

A water bubbler system was included to humidify the air because the -70°F dew point air was uncomfortable to breathe. By passing the inlet air through water, the dew point was raised to a comfortable level, between +40°F and +70°F. A dew point indicator was included in order to monitor the dew point and indicate the requirement to refill the bubbler reservoir.

5.3.5.2 LCG Cooling Water Supply System - The LCG worn by the test subject was supplied with cooling water by means of a recirculating flow system. The system consisted of an insulated reservoir, water pump, flow control valve, and a 3/8-inch I.D. plastic tubing loop connecting the garment and the pump/reservoir system. Crushed ice was used to cool the water in the reservoir. The water supply system was capable of supplying each of two LCG's with a maximum flow of at least four pounds per minute and a reservoir temperature range from + 32°F to room ambient. The above flow and temperature range proved adequate to maintain the test subject in the body temperature comfort range.

5.4 Photographic Support

Photographic coverage, both movies and still photographs, was provided by the MSFC Photographic Laboratory. The portion of the program during which human factors observations were gathered was provided with continuous motion picture coverage. A variety of viewing angles and distances were used during the test sequences to provide general and detailed views of all tasks and subtasks. Motion picture coverage of the portion of the test effort devoted to metabolic rate determination was provided in sufficient quantity to prepare a representative film record of the tasks and methods utilized.

Still pictures were taken, as requested by the test director, in order to provide the means for detailed study of discrete task and interface problems.

5.5 Conduct of Test

5.5.1 Scheduling

The schedule for the phase II portion of the experimental program is shown in figure 5.

During the conduct of the metabolic rate determination portion of the experiment, a rotational test subject schedule was followed. The schedule was arranged so that a subject was never required to work in the pressure suit on two consecutive days. This method was initiated in order to insure that: (1) the test subject was fresh and rested and, therefore, capable of the maximum stability and repeatability in performance, and (2) the minor abrasions caused by the suit and the biomedical sensors would have time to heal.

The total pressurized suit time accumulated during this phase of the test program was 176.3 hours.

5.5.2 Metabolic Rate Determination Method

Metabolic rates were obtained by means of indirect calorimetry, based on respiratory exchange. The prime parameters required by this method were respiratory volume, volume of oxygen consumed, and volume of carbon dioxide produced. These parameters were calculated utilizing data obtained through an analysis of the volume and constituent percentages of the exhaled breath which was collected by means of a modified open-loop type of respiratory system utilizing Douglas bags. The inhaled and exhaled gasses were separated by means of a medical respiratory valve. A gas analysis breathing valve, developed for this program by Hamilton Standard, was installed in the expired gas line. This valve enabled gases exhaled at pressures above ambient (3.7 psig) to be collected in a Douglas bag at ambient pressure. The contents of the Douglas bag were analyzed in the system described in paragraph 5.3.4 of this report.

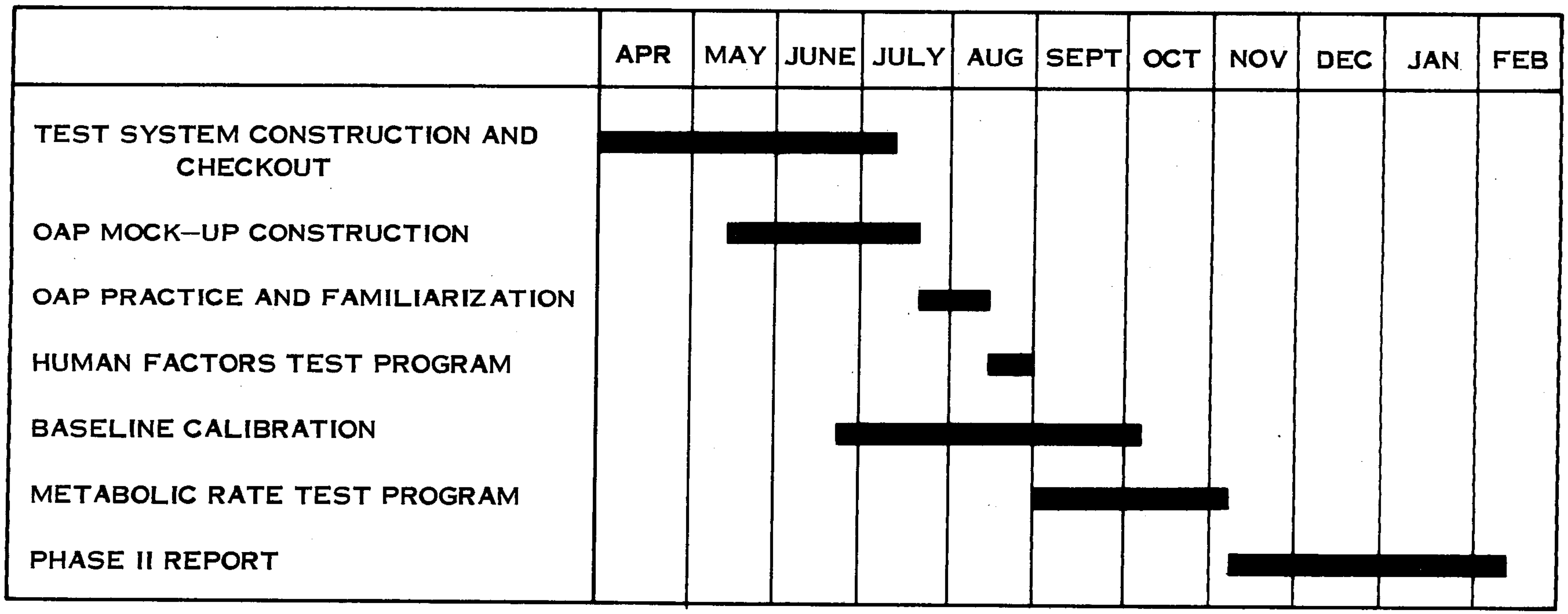


FIGURE 5. PHASE II SCHEDULE

5.5.3 Metabolic Rate Calculations

The following series of equations was utilized to convert the expired gas analysis data into a metabolic rate expressed in Btu/hr. The metabolic rate equation was derived from the Lusk Equation (reference: The Elements of the Science of Nutrition, Graham Lusk, 4th Edition, 1928).

5.5.3.1 Expired Volume - $\dot{V}_E$ STPD (Liters/Minute)

Data required

V_m = Sample volume as measured by dry gas meter - liters

V_s = Analysis volume extracted by syringe - liters

t = Time duration of sample collection - min.

P_b = Barometric pressure - mm Hg

T = Gas temperature - ^oR

P_{H_2O} = Partial pressure of water vapor, staurated at gas temperature (T) - mm Hg

$$V_E STPD = \frac{V_m + V_s}{t} \times \frac{P_b - P_{H_2O}}{760} \times \frac{460}{T}$$

P_{H_2O} may be obtained from a stream table such as: Thermodynamic Properties of Steam, Kennan & Keyes. The subtraction of P_{H_2O} from P_b converts the barometric pressure to a zero water vapor condition.

Medical standard temperature and pressure are 460^{o}R and 760 mm Hg, respectively.

5.5.3.2 Inspired Volume - $\dot{V}_I$STPD (liters/min)

Data Required:

$\dot{V}_E$ STPD

% E O_2 = Percent O_2 in expired gas.

% E CO_2 = Percent CO_2 in expired gas.

% I O_2 = Percent O_2 in inspired gas

% I CO_2 = Percent CO_2 in inspired gas

5.5.3.2 (Continued)

$$\dot{V}_I \text{ STPD} = \dot{V}_E \text{ STPD} \ \frac{100 - \%\ E\ O_2 - \%\ E\ CO_2}{100 - \%\ I\ O_2 - \%\ I\ CO_2}$$

This equation is dependent upon the premise that only oxygen and carbon dioxide are involved in the respiratory exchange. The subtration of the percentage of oxygen and carbon dioxide from unity produces the percentage of inert gas (primarily nitrogen) in the inspired and expired gas mixtures. As the actual volume of the inert gas does not change, the percentage ratio is equal to the total volume ratio $\frac{\dot{V}_I}{\dot{V}_E}$

If the test subject is in an equalibrium condition or working within his physical capabilities, this ratio will be 1.0 or greater. Any ratio less than 1.0 contains, therefore, a suspect piece of data.

5.5.3.3 Volume of Oxygen Consumed - $\dot{V}_{O_2}$ (liters/min)

Data Required:

$\dot{V}_I$ STPD

$\dot{V}_E$ STPD

$\%\ I_{O_2}$

$\%\ E_{O_2}$

$$\dot{V}_{O_2} = \dot{V}_I \text{ STPD } (\%\ I_{O_2}) - \dot{V}_E \text{ STPD } (\%\ E_{O_2})$$

5.5.3.4 Volume of Carbon Dioxide Produced - $V\ CO_2$ (liters/min)

Data Required

$\dot{V}_I$ STPD

$\dot{V}_E$ STPD

$\%\ I\ CO_2$

$\%\ E\ CO_2$

$$\dot{V}\ CO_2 = \dot{V}_E \text{ STPD } (\%\ E\ CO_2) - \dot{V}_I \text{ STPD } (\%\ I\ CO_2)$$

5.5.3.5 Respiratory Quotient - RQ

Data Required

$\dot{V}\ O_2$

$\dot{V}\ CO_2$

$$RQ = \frac{\dot{V}\ CO_2}{\dot{V}\ O_2}$$

5.5.3.6 Metabolic Rate - Q_m (Btu/hr)

Data Required

$\dot{V}\ O_2$

RQ

$$Qm = 60 \left[15.14 + 4.89\ (RQ)\right] \dot{V}_{O_2}$$

5.5.4 Base Line Calibration

Prior to initiating the OAP experiments, a baseline calibration was conducted on each test subject. This calibration, in a shirt sleeve mode, established the relationship of heart rate, respiration rate, deep body temperature, and walking speed to metabolic rate. The calibration was repeated in a pressure suit at 3.7 psig, to determine the metabolic cost of the pressurized suit as well as the relationships obtained in the shirt sleeve mode.

Both the shirt sleeve and suited baseline calibrations were conducted utilizing a treadmill as the exercise media. Biomedical data and metabolic rates were determined by means of the equipment and methods detailed in previous paragraphs of this report. Data was collected at standing rest and at a minimum of four walking rates covering a span to, at least, 2000 Btu/hr. The test subject was required to exercise, at each data collection point, for 10 minutes or until the biomedical parameters were stabilized, whichever was the greater time period. A minimum of two metabolic rates were determined at each exercise point to further insure accurate, stable calibration data.

5.5.5 Optical Astronomy Package Experiment

5.5.5.1 Metabolic Rate Determination - A Douglas bag sampling technique was employed to obtain a continuous average metabolic rate for the OAP experiment. This technique required that the expired breath be collected throughout the task sequence by immediately replacing filled Douglas bags with empty ones. The collection time duration of

5.5.5.1 (Continued)

each bag was two to five minutes, dependent on the work rate. The total energy expended during the sequence or the average metabolic rate for the entire sequence represents, therefore, a summation of average rates realized during two to five minute segments of the sequence.

The biomedical data (heart rate, respiration rate, and deep body temperature) were observed throughout the Douglas bag collection period and the average reading recorded on the test data sheet.

Each test subject performed a minimum of three sequences at each of the OAP stations. These replications were required to provide confidence in the data obtained, as well as provide the minimum base for a statistical data analysis.

5.5.5.2 Human Factors - The portion of the test effort directed toward the collection of human factors design criteria data involved direct observation of the experiments by the Hamilton Standard Human Factors Group representative. Eight complete test sequences, plus a number of partial sequences, were conducted under his observation. In addition, total motion picture coverage was provided during all sequences to allow further detailed study of all tasks. Still pictures were also provided, as required, for analysis of particular critical operations and tasks.

6.0 RESULTS

All human factors' observations and metabolic rate determinations, with the exception of the shirt sleeve baseline calibrations, were collected in an A4H or HECMAR pressure suit at 3.7 ± .2 psig and one-g conditions. The test subjects wore a Hamilton Standard liquid cooling garment for comfort control.

6.1 Accuracy

An error analysis was conducted in order to determine the confidence level associated with the calculated metabolic rates. A root mean square method of analysis was utilized which considered the accuracies of the instrumentation and the combined effect of these accuracies on the metabolic rate computations.

Each instrument used in the test setup had an inherent accuracy of ± 1% (F.S.) or better. This represented the maximum practical degree of accuracy that could be achieved without resorting to scientific laboratory or primary standard equipment. The accuracy, to one standard deviation, of the metabolic rates contained in this report was determined to be $\pm$ 4.9 percent. This degree of accuracy is as good as, or better than, the accuracy of any of the methods currently in use, and, considering the variations in human performance, is acceptable.

The metabolic rate data have been presented as calculated, however, due to the human variations and instrumentation accuracies as discussed above, the last two digits of these numbers are not significant.

6.2 Metabolic Rate Determination

6.2.1 Baseline Calibration

6.2.1.1 Metabolic Rate Versus Treadmill Speed - The shirtsleeve and pressure suited baseline calibration curves are contained in figures 6 through 11. The three test subjects were in excellent physical condition at the time of these tests, having participated in the exercise program for 8 to 10 months. The stability of physical performance as a result of a high level of physical condition can be observed in the minimal amount of data "scatter" in the shirtsleeve treadmill speed versus metabolic rate portion of figures 6, 7 and 8. Subjects B and C produced similar treadmill speed versus metabolic rate curves with subject B holding a slightly better performance up to the high work range (above 1500 Btu/hr.) where their performance curves are quite similar. Performance is defined here as the metabolic cost incurred during walking at a given speed. It can be related to the efficiency with which the body performs a given task. Subject A exhibited a marked performance advantage over both B and C throughout the upper calibration range, with subject B again exhibiting better performance in the low range.

6.2.1.1 (Continued)

The pressure suited baseline calibration, (figures 9, 10 and 11) illustrate the importance of the fit of the pressure suit, especially in the lower extremities and boots. The tallest subject (A) had the best suit fit. This is demonstrated by his increased performance over subjects B and C.

For the suited baseline calibration, conducted at 3.7 psig, subject C's performance was better than B's throughout the calibration range. This would indicate that the suit fit caused a reversal of the relative performances exhibited in the shirt sleeve calibration.

It is of interest to note that improper fit of the pressure suit caused a marked degree of change in performance of an individual on a day-to-day basis. These changes are exhibited as "scatter" on the treadmill speed versus metabolic rate curve. The data for subject C represented the results of one run, and all data points plot with negligible scatter. The curve for subject B exhibited the extreme case of the day-to-day change. The six plot points above the curve represent one daily run and the six plot points below the curve represent another. It can be seen that either set of data would, by itself, produce a smooth curve with negligible scatter.

6.2.1.2 Metabolic Rate Versus Heart Rate - A current rationale for metabolic rate prediction is to employ the heart rate as an indication of the imposed metabolic load; however, this relationship must be applied with reservation. Examination of the metabolic rate versus heart rate portion of figures 6 through 11 will indicate the validity and the limitations of this approach. In order to establish the tolerance band for metabolic rate prediction, it is necessary to place upper and lower limit boundaries around the representative heart rate curve. These limit boundaries must encompass all the plot points collected. By selecting any given heart rate and moving across the graph on that line, the predicted metabolic rate will be that range spanned by the limit boundaries. This concept is best illustrated on the shirt sleeve baseline calibration curves. The tolerance band varies from subject to subject, but, in general spans a range of 200 to 300 Btu/hr for subjects A and C and 400 Btu/hr for B. It had been noted throughout the test program that subject B had extremely rapid and active heart responses, both increasing and decreasing, which explain the broader tolerance band.

This concept of metabolic rate determination has several limitations (assuming that the above tolerance band is acceptable for the intended use).

These limitations are:

1. The curve should only be applied to the one subject for which it was plotted. In addition, the man must be in excellent physical condition in order to minimize the heart rate variations at any given work rate.

6.2.1.2 (Continued)

2. The man must be working in a physiologically stable condition in order that his heart rate does not reflect recovery from previous tasks.

3. The heart rate versus metabolic rate relationship is somewhat dependent upon the wearing apparel, especially at the lower work rates. The day-to-day variations resulting from suit fit which were noted in the treadmill speed versus metabolic rate curve appear, to a lesser degree, in the heart rate curve. The shirt sleeve heart rate curves also vary slightly from the pressure-suited curves.

In order to minimize the tolerance band, therefore, the calibration curve should contain stabilized data collected by one man in a well-fitting pressure suit, and should be considered valid for that suit/man combination only.

6.2.1.3 Respiration Rate and Deep Body Temperature Versus Metabolic Rate - The calibration curves of respiration rate versus metabolic rate and deep body temperature versus metabolic rate produce too small a parameter change per metabolic rate change and were too variable to prove of value in predicting or correlating metabolic rate. The primary value of these curves was in establishing "normal" reactions to metabolic loads. The data was used to monitor the physical well being of the test subject and provide early indication of overstress or potential exhaustion.

6.2.1.4 Metabolic Cost of the Pressure Suit - The metabolic cost of working in the A4H-035 Apollo Training Suit is contained in table I.

6.2.2 OAP Mission Metabolic Requirements

6.2.2.1 General - During the time between the baseline calibration and the metabolic rate determination test, subject C incurred an ankle injury which prevented his participation in the daily physical conditioning program for approximately five weeks. At the initiation of the OAP metabolic rate experiments, C had experienced a degradation of physical condition of approximately 30 percent, as evidenced by the Harvard Step Test score. The level of physical condition remained above average, but a loss of physical stability and diminished correlation to the baseline calibration data resulted. The time schedule for the experiments and subject C's terminating his employment prevented the establishment of a new baseline calibration at the lower performance level.

A tabular summary of the data collected for the total task and the major subtasks is exhibited in table II.

Graphic representations of the 22 task sequences conducted by the three test subjects are located in appendix B.

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

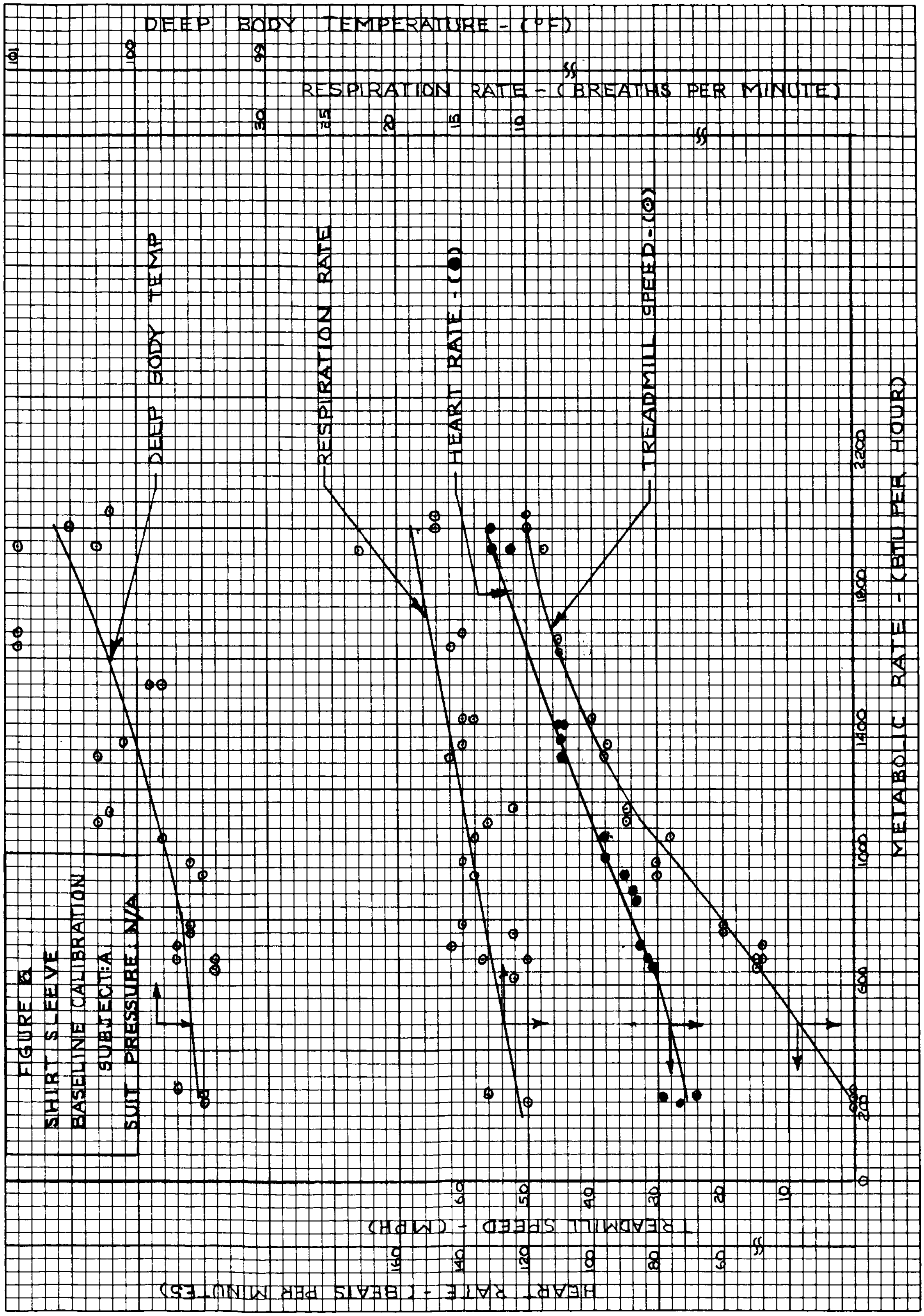
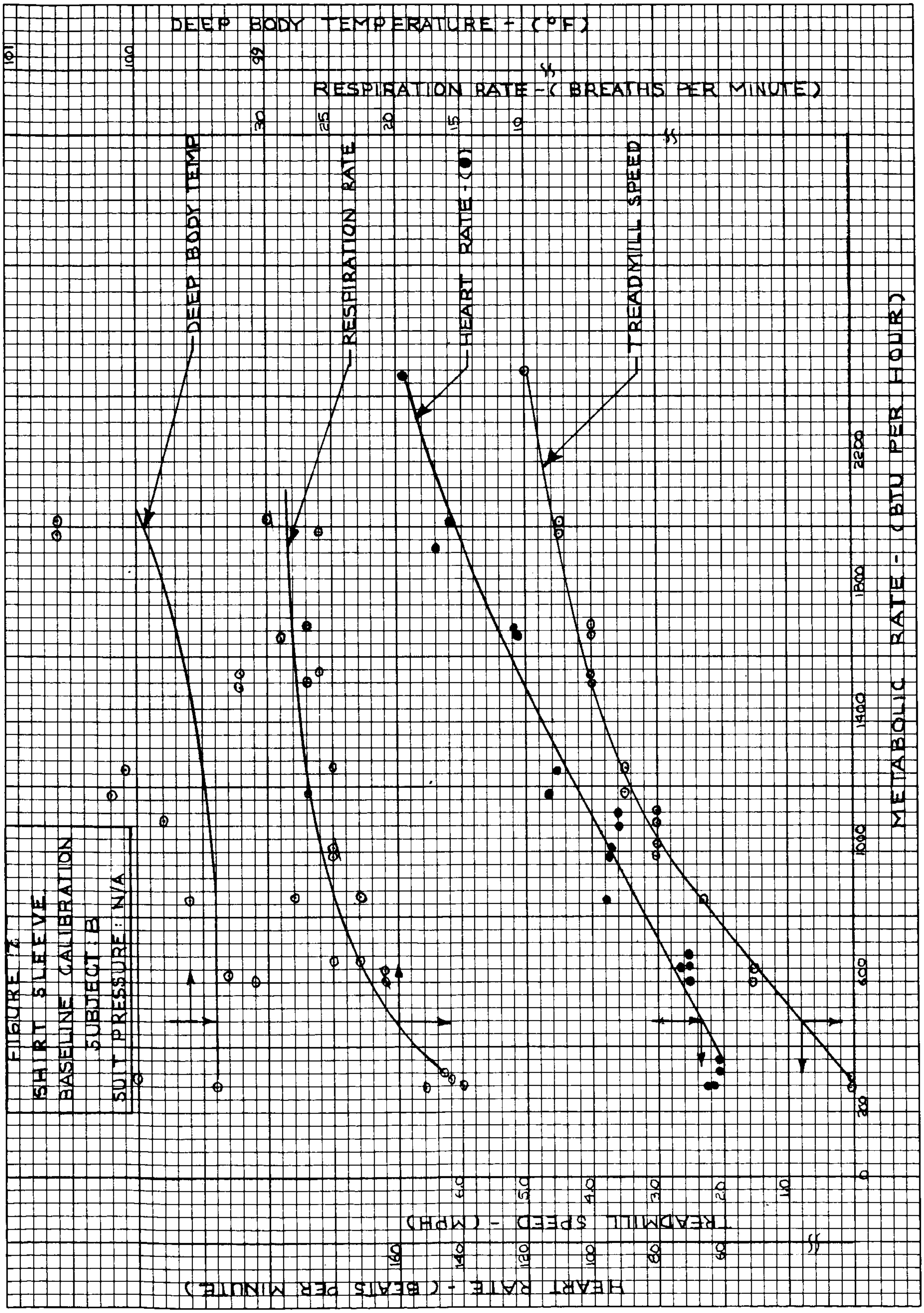
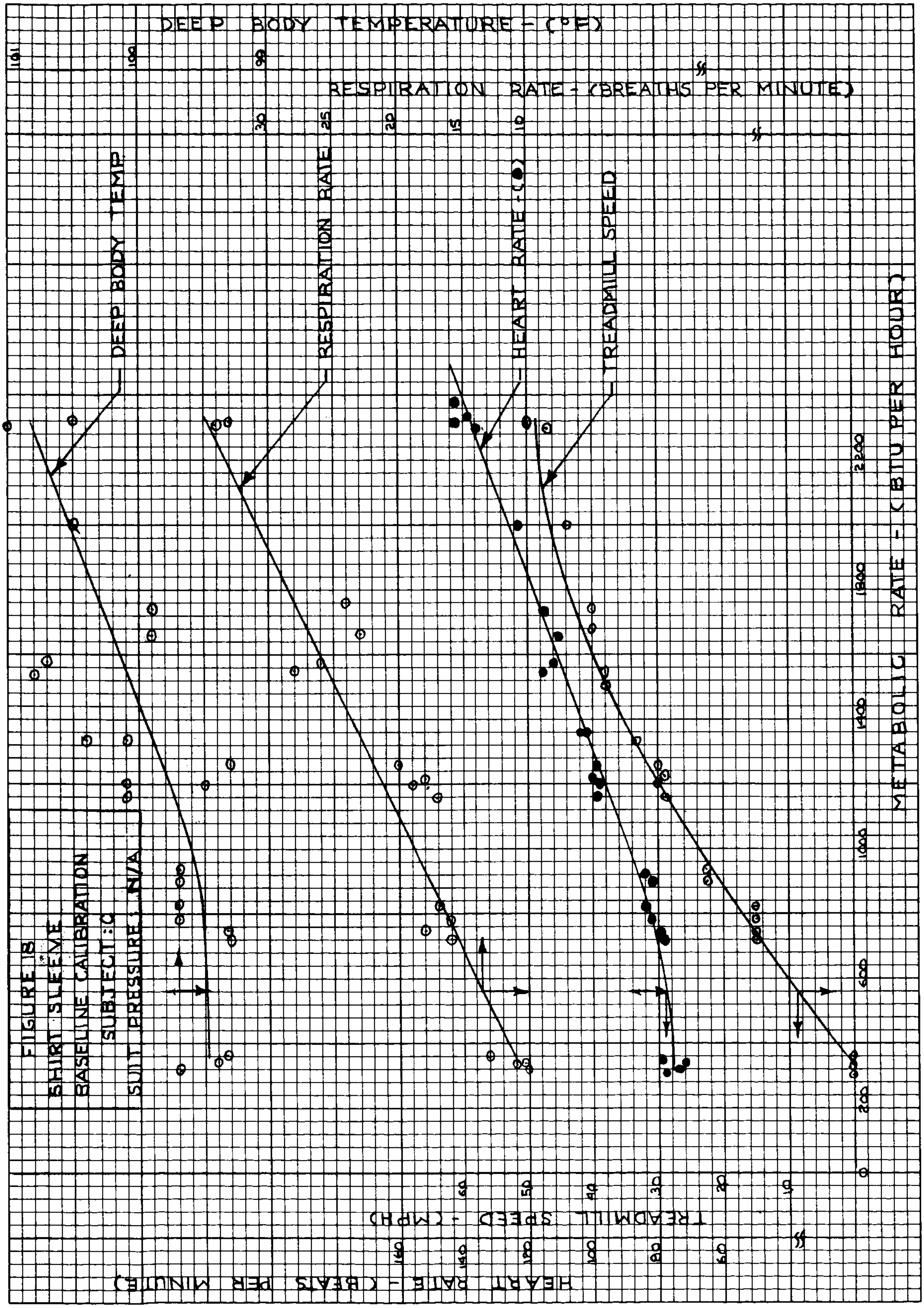


FIGURE 6
SHIRT SLEEVE
BASELINE CALIBRATION
SUBJECT: A
SUIT PRESSURE: N/A


DEEP BODY TEMPERATURE - (°F)
RESPIRATION RATE - (BREATHS PER MINUTE)
DEEP BODY TEMP
RESPIRATION RATE
HEART RATE - (●)
TREADMILL SPEED
METABOLIC RATE - (BTU PER HOUR)
TREADMILL SPEED - (MPH)
HEART RATE - (BEATS PER MINUTE)
FIGURE 7
SHIRT SLEEVE
BASELINE CALIBRATION
SUBJECT B
SUIT PRESSURE: N/A


DEEP BODY TEMPERATURE - (°F)
RESPIRATION RATE - (BREATHS PER MINUTE)
DEEP BODY TEMP
RESPIRATION RATE
HEART RATE - (●)
TREADMILL SPEED
METABOLIC RATE - (BTU PER HOUR)
TREADMILL SPEED - (MPH)
HEART RATE - (BEATS PER MINUTE)
FIGURE 18
SHIRT SLEEVE
BASELINE CALIBRATION
SUBJECT: C
SUIT PRESSURE: N/A

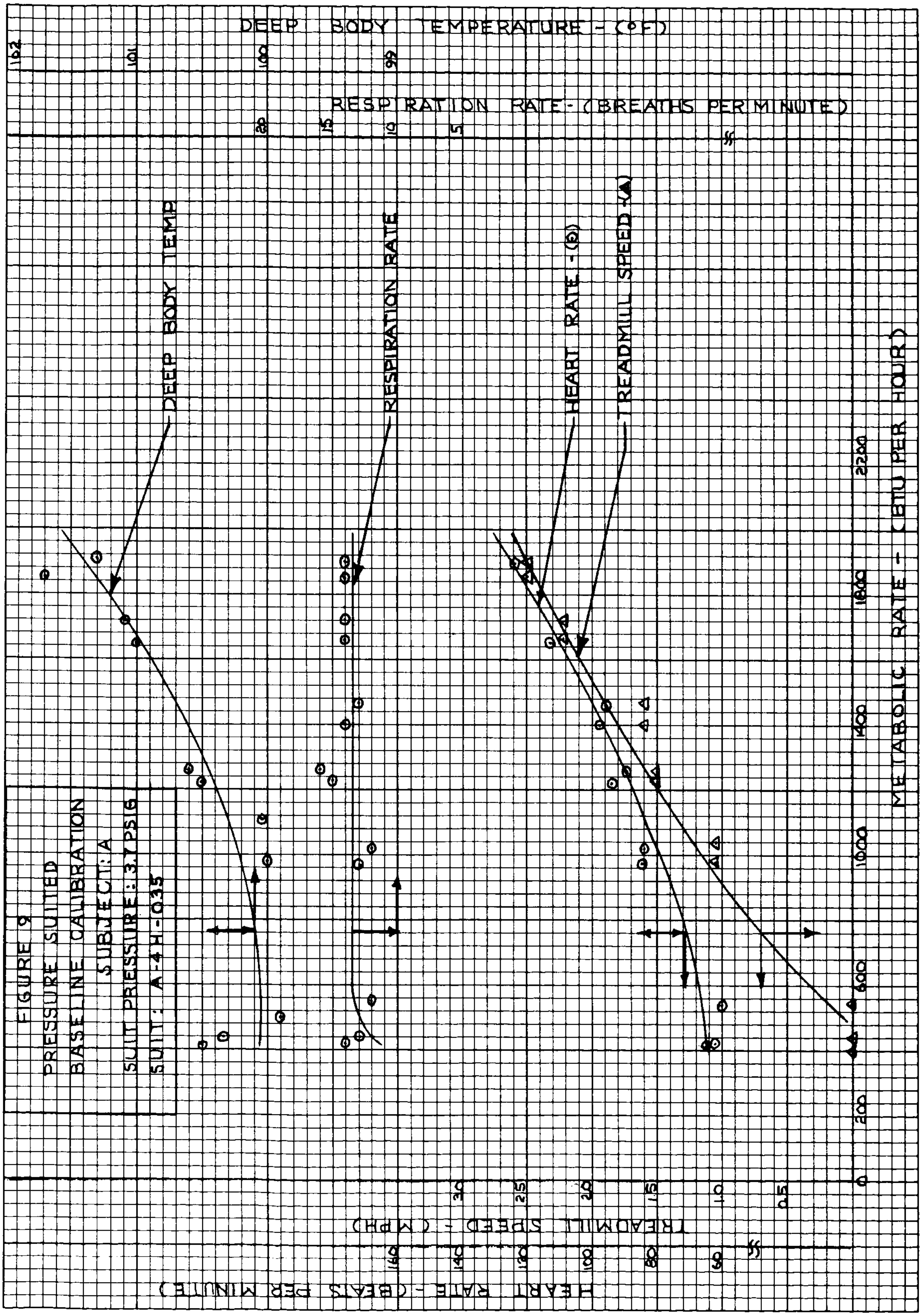


FIGURE 9
PRESSURE SUITED
BASELINE CALIBRATION
SUBJECT: A
SUIT PRESSURE: 3.7 PSIG
SUIT: A-4H-035

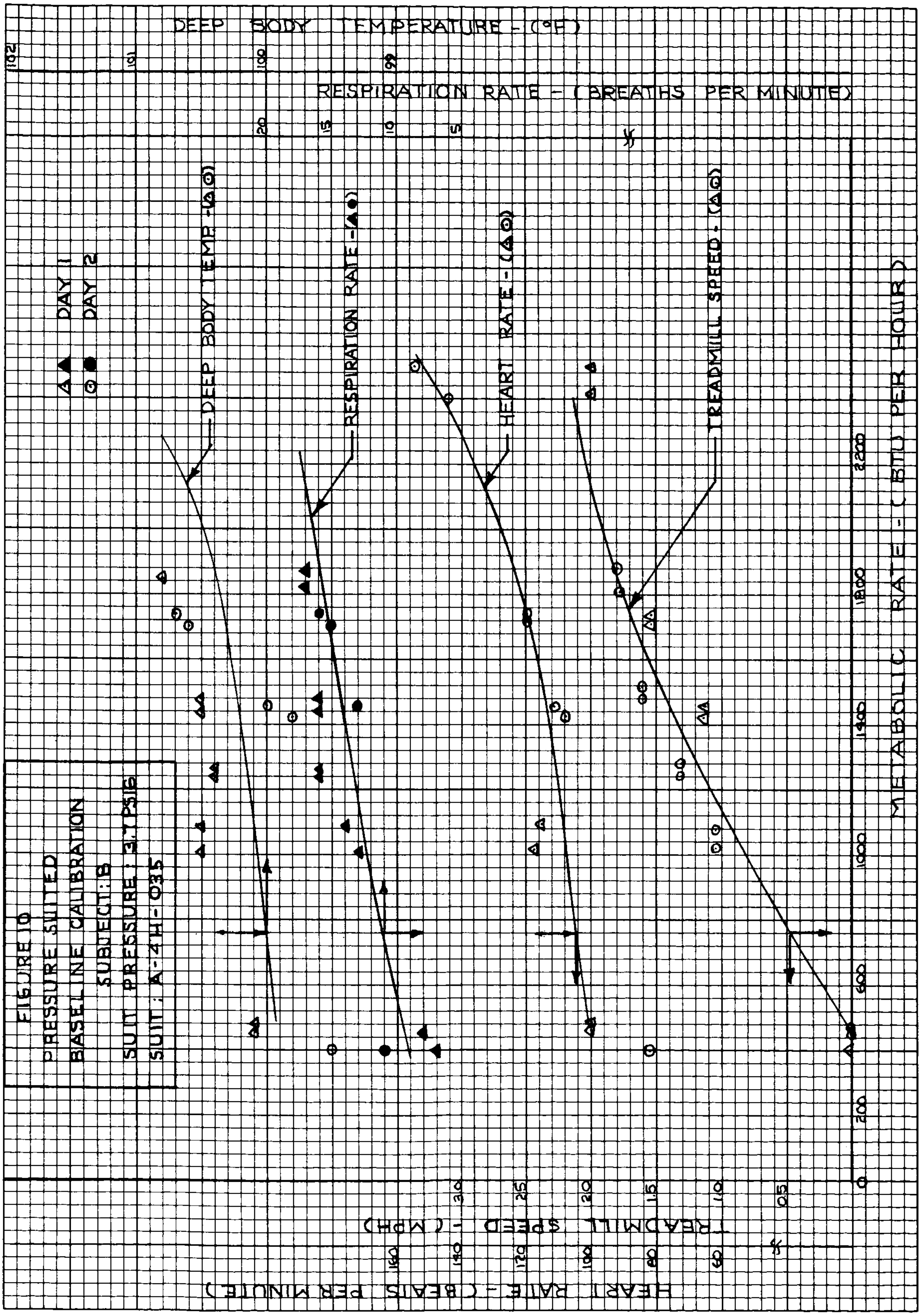


FIGURE 10
PRESSURE SUITED
BASELINE CALIBRATION
SUBJECT: B
SUIT PRESSURE: 3.7 PSIG
SUIT: A-4H-035

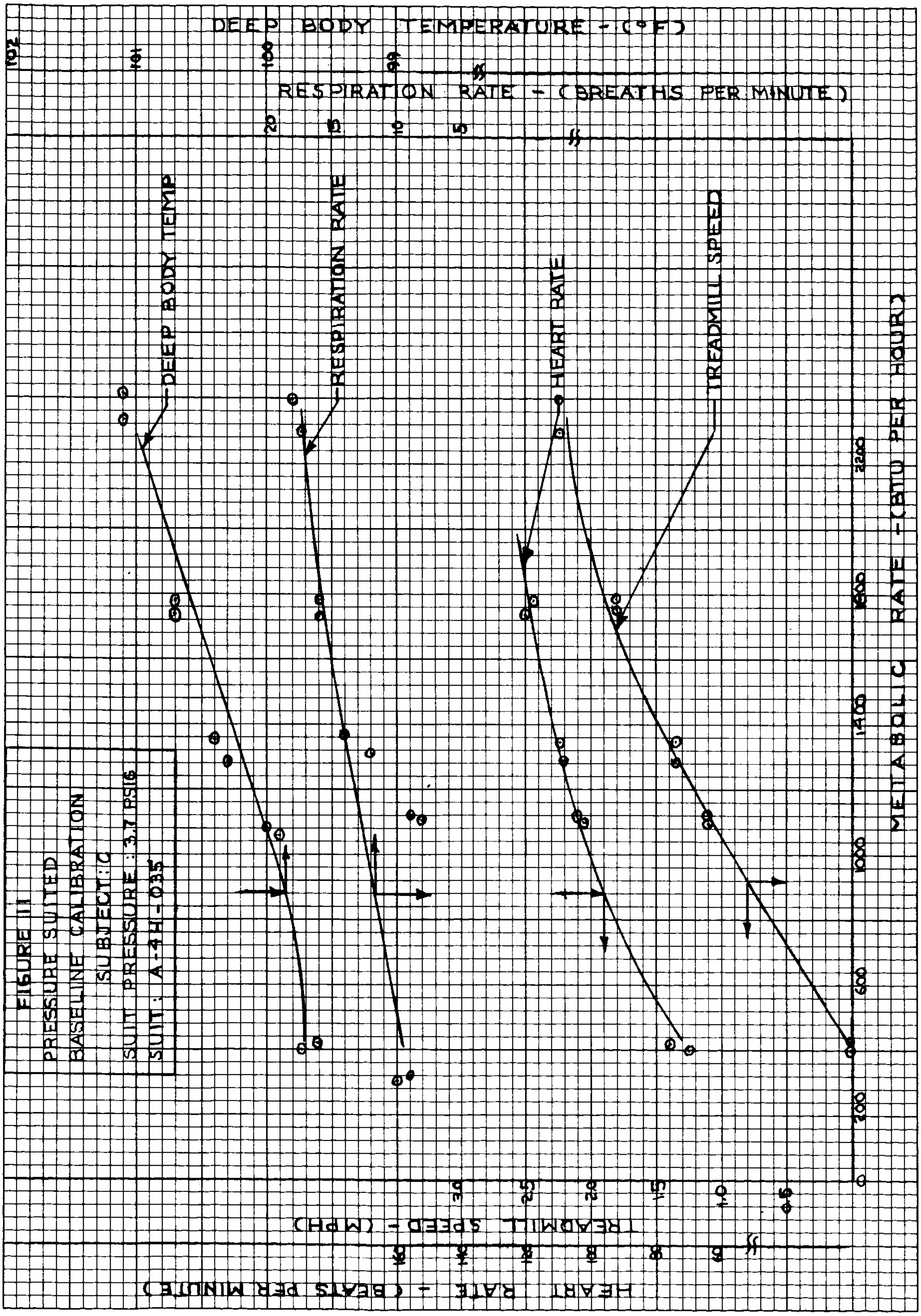


FIGURE 11
PRESSURE SUITED
BASELINE CALIBRATION
SUBJECT: C
SUIT PRESSURE: 3.7 PSIG
SUIT: A-4H-035

METABOLIC COST OF A4H-035 APOLLO TRAINING SUIT

TABLE I

Test Subject	Treadmill Speed MPH	Metabolic Rate Shirtsleeve Btu/hr	Metabolic Rate A4H-035 Pressure Suit Btu/hr	Pressure Suit Cost (Qm Suited - Qm Shirtsleeve) Btu/hr
A	1.0	550	920	370
A	1.5	670	1190	520
A	2.0	770	1500	730
A	2.5	880	1850	970
B	1.0	510	1110	600
B	1.5	620	1520	900
B	2.0	745	2050	1305
C	1.0	590	1050	460
C	1.5	730	1410	680
C	2.0	870	1870	1000

6.2.2.2 Total Energy Expenditure - The average metabolic requirements for the OAP erection and deployment task are illustrated in columns 1 and 2 of table II. The averages were based on four sequences at each position for subjects A and B and three sequences at each position for subject C. Subject C exhibited significantly higher average metabolic rates at both positions.

This apparently was the result of the degradation in physical condition discussed in paragraph 6.2.2.1. The higher level of performance for subject A, which was noted in the pressure-suited baseline calibration, was not apparent in the data obtained at either work position.

This was the expected result as the performance of the task sequence involved a variety of tasks utilizing complex motions of all the pressure suit joints, rather than just the lower torso and joints employed in walking on the treadmill. Since walking and climbing was a minor portion (with respect to time) of the total task, subject A's advantage was negligible.

The average task time for each position is shown in columns 3 and 4 of table II. The average energy/time requirements for the OAP erection and deployment were:

Position A - 947 Btu/hr for 26.1 minutes
Position B - 1008 Btu/hr for 24.8 minutes

The total energy expenditure for this portion of a total mission was, therefore, 412 Btu for position A and 416 Btu for position B.

6.2.2.3 Ladder Climb - The most physically demanding task in the entire sequence was climbing the vertical ladder, 9.3 feet to the top of the LM shelter. Metabolic rates for the ladder climbing task were based upon climbing the ladder in 30 seconds and resting 30 seconds at the top. The rest at the top allowed for the lag in response of the human body. Three to five replications of this procedure were included in each collection bag. Sufficient recovery time was allowed between replications to return biomedical parameters to standing rest values.

The average metabolic rate, average heart rate, maximum heart rate, and average respiration rate are tabulated in columns 5, 6, 7, and 8, respectively, of table II.

The general relationships between the three test subjects observed during the baseline calibrations were valid for the ladder climb. This would seem logical because the task is one primarily involving the lower torso and legs. The evidence of poorer physical condition for subject C, however, was not observed for this task.

The biomedical parameters were considerably higher than those recorded at similar metabolic rates during the calibrations. This would indicate that, if the test subject continuously climbed at a rate of 9.3 feet per 30 seconds until stabilization occurred (approximately 10 minutes) the metabolic rate would be considerably higher. However,

TABLE II
METABOLIC DATA SUMMARY
OAP TASKS

	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6	COLUMN 7	COLUMN 8	COLUMN 9
TEST SUBJECT	POSITION A METABOLIC RATE (AVERAGE) BTU/HR.	POSITION B METABOLIC RATE (AVERAGE) BTU/HR.	DEPLOYMENT TIME		LADDER CLIMB				PLATFORM & LADDER DESCENT & ASCENT METABOLIC RATE (AVERAGE) BTU/HR.
			POSITION A MINUTES	POSITION B MINUTES	METABOLIC RATE (AVERAGE) BTU/HR.	HEART RATE (AVERAGE) BEATS/MIN.	HEART RATE (MAXIMUM) BEATS/MIN.	RESPIRATION RATE (AVERAGE) BREATHS/MIN.	
A	849	980	26.2	24.1	1160	113	148	14	1330
B	897	907	26.6	25.6	1435	154	166	20	1592
C	1095	1140	25.6	24.8	1309	143	152	19	1450
GRAND AVERAGE	947	1009	26.1	24.8	1321				1484

6.2.2.3 (Continued)

the metabolic expenditure recorded was valid for the short duration task.

In order to verify the assumption that stabilization had not occurred, a task sequence for position A which required a climb down and back up the ladder with little rest between was selected for further study. The task selected was one which required the test subject to dismount the work platform, climb down the ladder, hook the telescope to the hoist, climb up the ladder and remount the work platform. The time period for this series of tasks was 2.0 minutes and was followed by a 30-second rest on the work platform to simulate the time lapse before the test subject would again begin to actively work. The metabolic rates determined for this activity are shown in column 9 of table II. The biomedical parameters were similar to those observed in the 30-second ladder climb, but the metabolic rates were higher in every case, thus, supporting the assumption that stabilization had not occurred.

6.2.2.4 Walking (Position B) - Movement about the base of the LM shelter was a side step performed while facing the LM shelter, due to the 15.75 inch width of the walkway. The metabolic cost of this maneuver was examined in order to determine the significance of this task when compared to the total sequence, or the ladder climbing task.

It was determined that the metabolic cost of this side step, performed at a pace comfortable to the subject, was between 822 and 932 Btu/hr for the three men. This value was less than the average cost for the total sequence, so no further examination was justified.

6.3 Human Factors

During the human performance test simulations, eight complete mission profiles (sequence blocks 123 through 408) were accomplished. In addition, several partial runs were accomplished to ensure the identification and subsequent evaluation of all existing human interfaces.

The OAP erection and deployment tasks were observed and subsequently evaluated at two separate crew stations:

- Position A - this specific work area consisted of the LM shelter roof and the work platform (Man 1 in the timeline analysis).
- Position B - this specific work area consisted of the upper level of the LM shelter descent stage, including the OAP storage area, the access walkway, and the ladders (Man 2 in the timeline analysis).

6.3 (Continued)

Each of these crew stations was subsequently divided into the following five mission phases:

Erect the derrick (Ref. Blocks 125, 129 - 167).

Unstow, hoist and position the yoke assembly (Ref. Blocks 171 - 174, 178 - 230).

Unstow, hoist and position the telescope assembly (Ref. Blocks 270 - 330).

Retract the derrick into the stowed position (Ref. Blocks 346, 363).

Gross position the OAP assembly and enter LM shelter (Ref. Blocks 378, 408).

The specific criteria used to evaluate each of the mission tasks were as follows:

1. Crew functional task requirements

   A) To operate

   B) To control

   C) To monitor

2. Work space requirements

3. Maintainability requirements

4. Crew safety requirements

The overall selection of applicable design criteria was based entirely upon the observations obtained and subsequent evaluations of data generated during the test sequences at the MSFC TAF. The specific design criteria inputs have been taken from the following sources:

A. Direct measurements taken during the human performance testing program at the MSFC TAF.

B. Research of applicable documents with specific emphasis being placed upon the interpretation of the information related to pressure suits.

C. General research and development design criteria acquired as a result of Hamilton Standard pressure suit development, evaluation, and test simulation efforts.

6.3 (Continued)

The reference numbers (A, B, and C), when applicable, are noted in the design criteria subparagraphs.

6.3.1 Man-Equipment Interfaces

All mockup dimensions used in this section of the report are approximate values measured with a steel tape during the testing period.

6.3.1.1 The OAP Control Box (See figure 12) - The dimensional profile of the control box body consisted of a rectangular unit (length 7 1/2 inches, width 3 1/4 inches, depth 2 1/4 inches) designed to be held in one hand. Control actuation was accomplished with the other hand. The depth dimension should be considered as a maximum value to permit grasping with the pressurized glove. In its present configuration, the unit could be easily grasped.

The control box handle consisted of a thin U-shaped bar, vertically oriented on each side of the control box. The orientation and location of these handles was very effective but the dimensions of the actual grip handles (elliptical cross section 5/8-inch major axis, 3/8-inch minor axis) was considerably below acceptable limits for a pressurized glove interface.

The handle access, dimensional profile (palm-grip length 6 1/4 inches, palm-grip thickness 1 1/2 inches) provided an adequate pressurized glove interface.

It should be noted that because of the large access profile and the ineffective handle grip area, the test subjects used the control box thickness as the grasp area, and the handle functioned as a guard. This did not provide positive control of the unit.

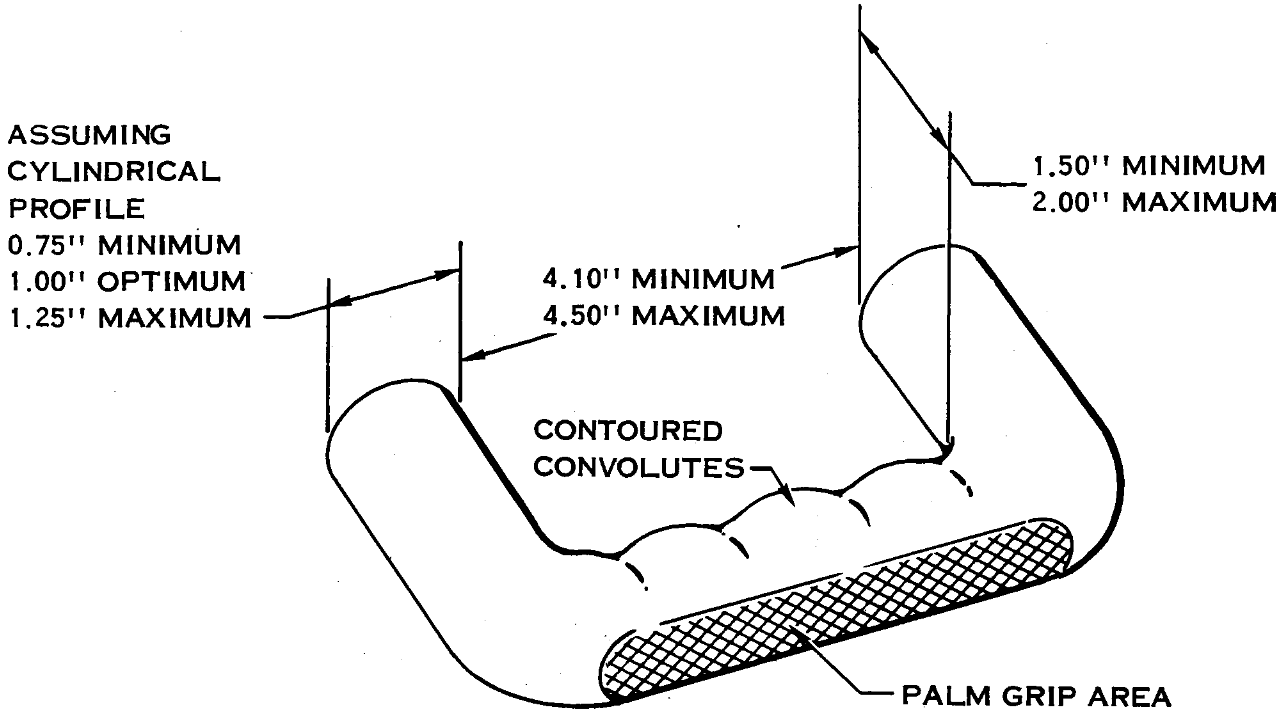
6.3.1.1.1 Design Criteria, Handles and Grasp Areas - (Ref. A., B., Design Criteria Handbook for Lunar Scientific Equipment, Revision 1 January 15, 1967, SVHSER 3998) The OAP functional mockup used handles and/or grasp areas with little or no emphasis upon the pressurized glove grasp capability. Because of the mobility and dexterity restrictions and the dimensional profile of pressurized glove, the following design features should be incorporated into handles:

- The semirigid palm restraint used in the pressure glove requires a mating surface to allow more contact area.

- The cross sectional grip profile, excluding the palm restraint area, should incorporate circumferentially oriented convolutes in order to provide an effective grasp for each finger.

An example of this configuration immediately follows.

TYPICAL U BAR HANDLE

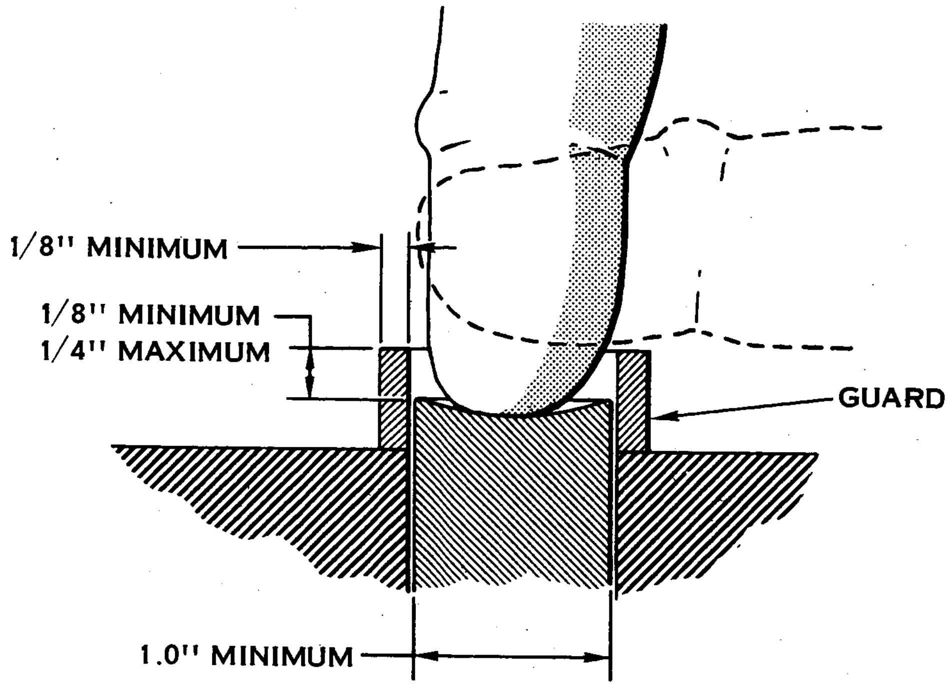


.3.1.2 Control Buttons - The mockup control box display consisted of four circular, concave pushbutton controls (1- inch O.D.). The two vertically oriented buttons on the right side of the display activated the winch assembly, and the two vertically oriented buttons on the left side of the display activated the derrick assembly. The pushbutton spacing (vertical clearance 1-5/8 inches, horizontal clearance 3/4 inch, edge-to-edge) was adequate for the number of controls displayed and the type of display presentation. Because the pushbuttons were unguarded, the pressurized glove contacted and actuated an adjacent control during several control sequences. The present configuration was, therefore, not effective in providing protection against inadvertant operation during one-hand operation.

.3.1.2.1 Design Criteria, Control Guards - Because of the volumetric increase of each finger of a pressurized glove and the reduction of tactile and positional feedback, controls should incorporate a barrier or guard to eliminate inadvertent operation.

The guard should be designed to require a definite control motion on the part of the crewman to activate the control. An example of this guard immediately follows.

TYPICAL PUSH BUTTON CONTROL GUARD



.3.1.3 Control Displays - The control orientation, winch "raise" above "lower" and derrick "extend" above "retract" was an effective control presentation.

Control labelling was adequate in content and orientation but should have used larger characters for the most effective presentation. Assuming a maximum viewing distance of 28 inches and the possibility of an illumination level below one foot lambert, the height of label characters should be 0.2 to 0.3 inches (Ref. B, MIL-STD 803A-1).

The control box display used an indicator light to indicate that a power-on condition existed. As the indicator light was located on the top end of the control box, it was not an adequate warning device. The warning light indicator should have been positioned at the upper extreme of the display panel, and labelled according to its functional indication - "power-on". A level of brightness was not established for the existing light but it appeared sufficient for the intended purpose.

3.1.4 Electrical Cables and Connection - A Cannon type electrical plug and receptacle were used to provide a control box - electrical cable connection. In the present configuration, a time consuming pin alignment and twisting motion was required to engage and lock the connector. Although connection of this plug was not a required task, a simple push to engage and a 1/4-turn-to-lock type of connector should be used in order to provide an effective pressurized glove interface. The O.D. grip ring on the plug should have a minimum diameter of 3/4 inch and an optimum diameter of one inch. (Ref. A, B, Design Criteria Handbook for Lunar Scientific Equipment, Rev. 1 January 15, 1967 SVHSER 3998).

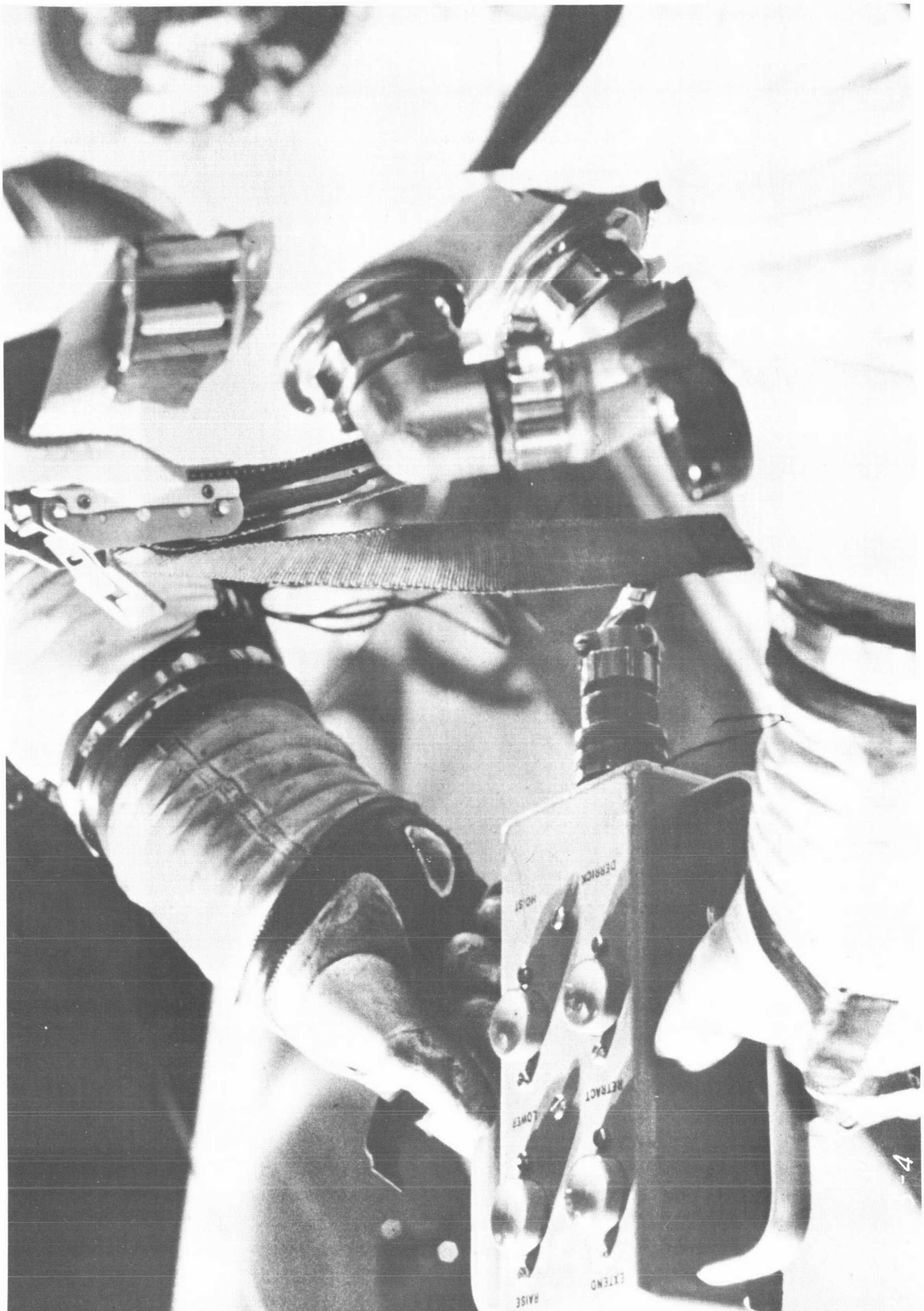


FIGURE 12

TEST SUBJECT USING OAP CONTROL BOX

6.3.1.4 (Continued)

An electrical cable was used to complete the power control circuit (control box - electrical terminal box). This lengthy cable provided the crewman with the range of movement necessary to reach all work areas on the LM shelter roof. The cable did, however, present a hazard to the pressure-suited crewmen. It was difficult to control the position of the cable relative to mission hardware in the work area, and it was possible to become tangled in the cable.

The incorporation of a recoil device to facilitate storage and handling of the cable would considerably reduce the crew hazard. The cable should be deployed by applying a noticeable steady tension, and retracted by releasing a recoil lock. The cable should hold any deployed position without a continuous application of force by the crewman. (Ref. A, B, Design Criteria Handbook for Lunar Scientific Equipment, Rev. 1 January 15, 1967, SVHSER 3998).

6.3.1.5 The OAP Electrical Terminal Box - The OAP functional mockup used a rectangular electrical terminal box which was rigidly mounted to the outer surface of the right A-frame derrick leg. The accessibility of the terminal box for maintenance or replacement tasks, was dependent upon the position of the derrick leg relative to the work area.

Five Cannon type electrical plugs and receptacles were used to provide the terminal box-electrical cable connection. This type of connector required a time consuming pin alignment and twisting motion to engage and lock the plugs.

Six standard cartridge fuses were located in a single, centrally oriented line on the lower surface of the terminal box. These units could be removed and replaced, but because of the small diameter and grip depth, they did not present an effective pressurized glove interface.

A grip depth of 1/2 inch combined with a 3/4 inch diameter should be considered the minimum size for satisfactory handling of the unit (Ref. A, C.).

When the derrick was in the stowed position, the terminal box orientation, relative to the LM shelter workspace, was such that the electrical connectors and the fuses were accessible only by means of a hazardous crew action. When the derrick was extended into its mission configuration and reached a position approximately 30° above horizontal, the terminal box electrical connections became accessible for maintenance, repair and replacement. The terminal box remained at a 16 inch horizontal reach distance from the edge of the LM shelter work space, which represented a safety hazard. The electrical terminal box should be incorporated into the work platform area making it easily accessible to the crewman during the entire mission.

6.3.1.6 The OAP Derrick Assembly Latch - (See figure 13) The OAP derrick A-frame structure used three manually engaged mechanical locks which coupled the two folding sections of each derrick leg into rigid support members. The locks were engaged by a crew member

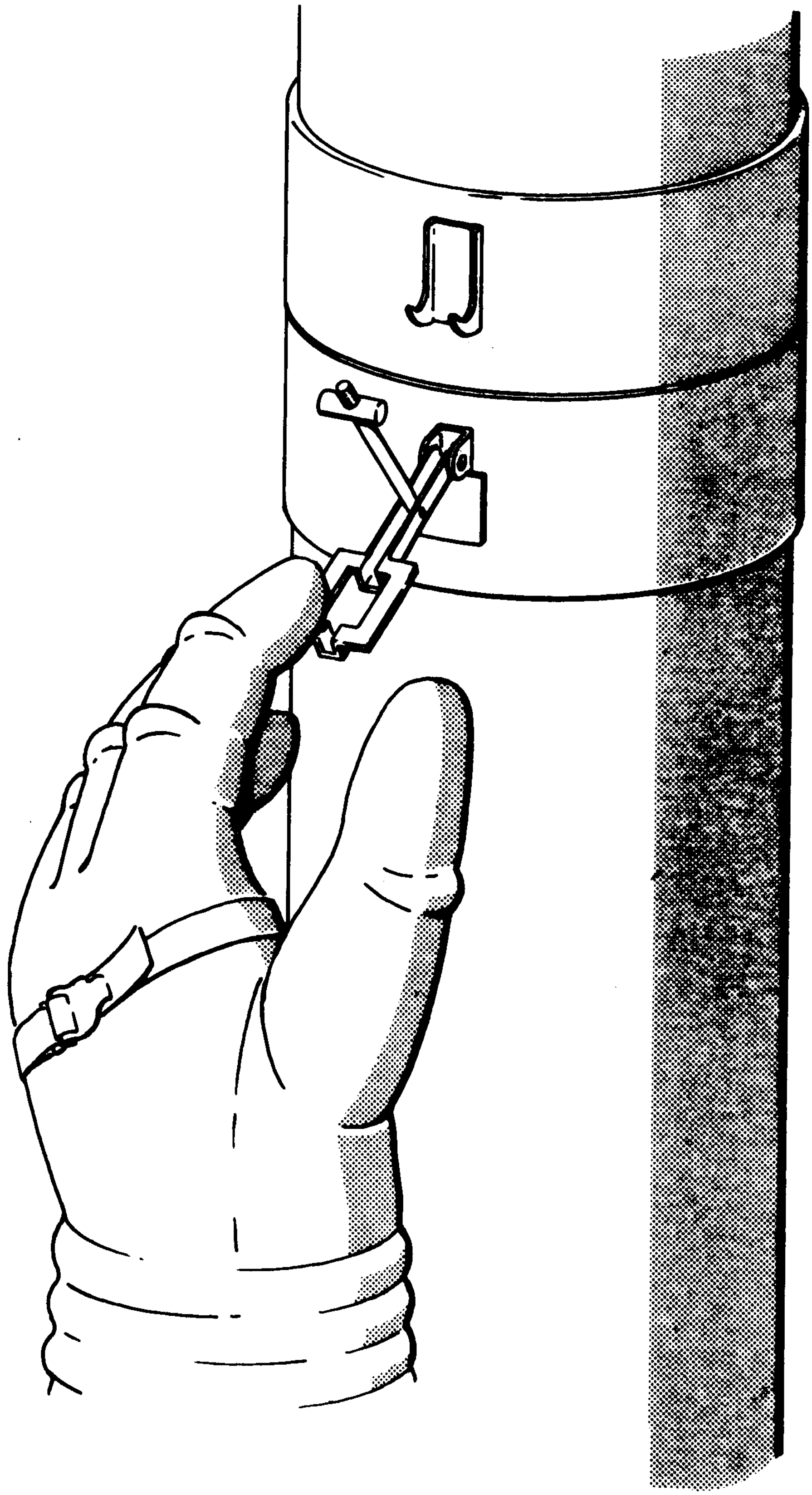


FIGURE 13. TEST SUBJECT ACTUATING THE OAP DERRICK, "A" FRAME LEG LATCHES

6.3.1.6 (Continued)

when the derrick had extended to a position approximately 45° above the horizontal.

The activation tasks required to engage the presently configured locks presented an undesirable pressurized glove - hardware interface from the standpoint of dexterity requirements and potential glove damage.

The activating sequence consisted of grasping a rectangular thin flanged grip area, rotating the unit about the pin on the top end, and removing the cylindrical locking device from its recessed storage position in the handle. Both of these tasks were performed with one hand. Next, the cylindrical locking device was extended and engaged into the locking receptacle by continuing to rotate the entire handle unit. When the lock was engaged, the handle was pressed back into a position flush with the leg to secure the lock. This was accomplished with the heel of the palm and caused damage to the gloves.

The locks had a tendency to bind or tighten up in the engaged position, and required considerable force to disengage. This resulted in excessive glove wear in the areas of the thumb and first three finger tips.

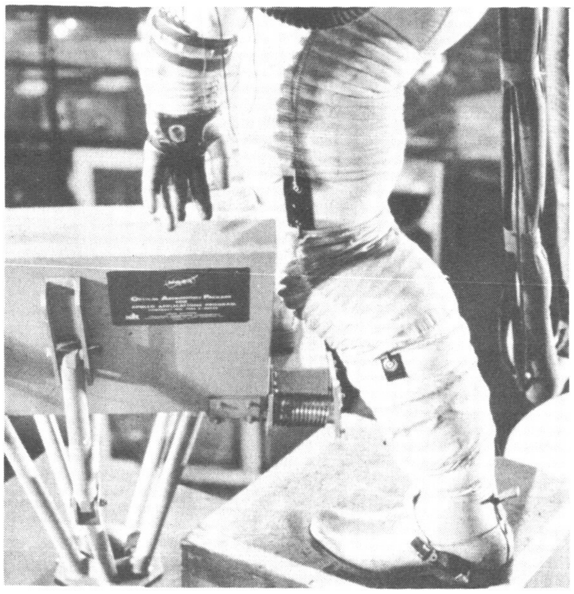
6.3.1.6.1 Design Criteria Latches (Ref. A and C) - The thin flange latches such as those used on the A-frame leg locks did not provide a satisfactory pressurized glove grip area, and resulted in unnecessary hand fatigue and glove wear.

This type of locking mechanism and actuating device used in combination with a palm grasp lever, similar in design to the handle of a pliers, would provide a most effective glove interface. The mechanical advantage would also be increased.

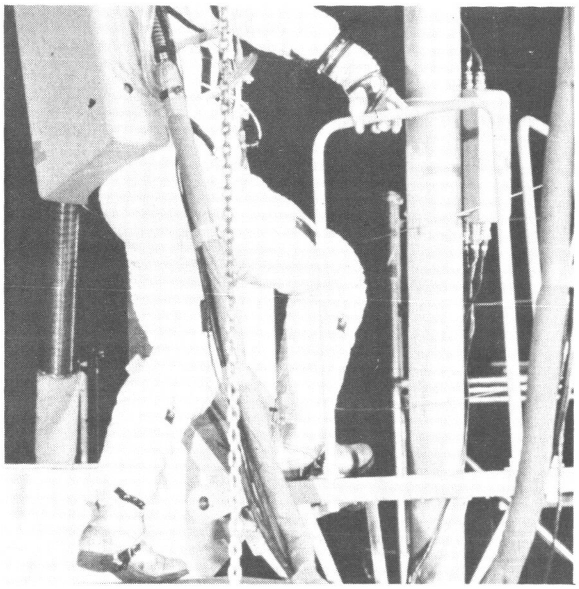
The actuation handle should have a minimum cross section of 3/4 by 1/4 inches and a minimum handle length of 2-1/2 inches. The access clearance between the handle and the base structure should be 1-1/2 inches. The handle should have no sharp edges. This type of actuation handle is designed for two finger operation.

6.3.1.7 The OAP Work Platform (See figure 14) - The OAP functional mockup used an elevated work platform and retractable extension which was primarily an isolated control area. It provided a more effective view of the entire work area, and increased the accessibility of the OAP assembly in its deployed configuration.

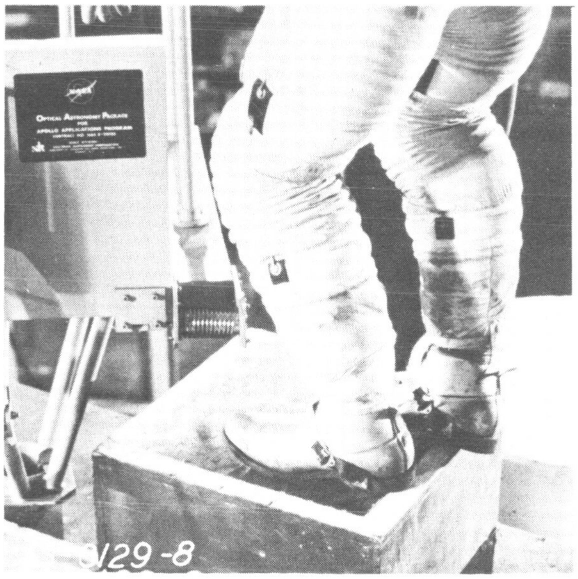
The dimensional profile of the work platform (length 30 inches, width 30 inches) provided approximately 900 square inches of work space. The platform extension (length 22 inches, width 30 inches) provided an additional 660 square inches of area. This total area provided sufficient work space for the pressure-suited crew member to accomplish the task requirements.



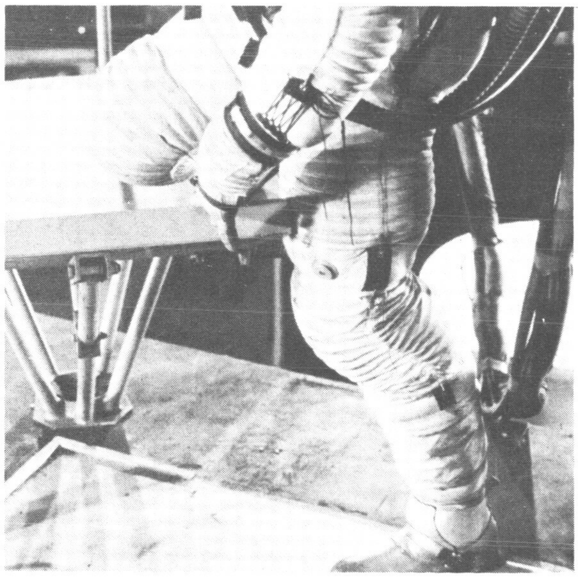
WORK PLATFORM MOUNTING AID



ASSISTED MOUNTING ATTEMPT



PLATFORM EXTENSION INTERFERENCE



UNASSISTED MOUNTING ATTEMPT

FIGURE 14

6.3.1.7 (Continued)

Accessibility of the work platform was definitely inadequate for a pressure-suited crewman. A horizontal step distance from the LM shelter work area of 13 inches and a vertical step of 20 inches were required to mount the platform. Because the work platform was mounted outside the roof work area, the crewmen was placed in an extremely hazardous position when mounting the platform. The addition of another step was necessary to reduce the step dimensions to usable values.

The work platform extension was a spring-loaded retractable work area which provided greater horizontal accessibility to the OAP assembly. The effectiveness of this work area could be increased by elevating it above the level of the basic work platform. In addition, this concept would allow the basic platform to be lowered, thus reducing the step dimension.

The base work platform incorporated a safety hand rail on two of the three sides facing away from the LM shelter work area. Because of the psychophysiological stress of working in a pressure-suited environment and at a hazardous height, the design of these hand rails was inadequate. A safety barrier, to eliminate the possibility of slipping off the work platform, should be provided on every exposed side of the work area.

The present height of the hand rail (33 inches) was inadequate as a safety barrier.

6.3.1.7.1 Design Criteria, Safety Barriers (Ref. A, B, MSFC STD 267A Table 15) - Elevated work areas should be provided with safety barriers about the exposed sides. The barriers must, of course, be an optimum design which considers weight and envelope as well as safety.

The height of the barrier should be just above waist height, 45 inches, and below nipple height, 53.9 inches. If a U-shape tubular safety barrier is used, a safety net or webbing should be included to prevent the crewman from stepping under the barrier and off the platform.

6.3.1.8 The OAP Unit Lift Points - The telescope and yoke assemblies used a steel eye bolt lift point to interface with a standard steel industrial hook on the winch assembly.

The telescope lift points (height 61-1/2 inches above the base) were readily accessible in the stowed position, but required excessive reach mobility in the deployed configuration.

The yoke lift points (height 69-1/2 inches above the base), although readily accessible in the deployed position, required the crewman to attempt an awkward and possibly hazardous reaching task in the stowed position. The crewman was required to move between the yoke and the LM shelter to reach the outer lift point. This was an undesirable situation which could be eliminated if the yoke was accessible from both sides of the LM shelter.

.3.1.8 (Continued)

The winch lift hook was a standard industrial unit which, because of its simplicity, could readily be adapted to this type of task. When the hooks were lowered into an accessible position, the task of engaging the hooks into the eye bolts was accomplished with very little wasted motion. A safety latching device was incorporated into the jaw of the hook to prevent inadvertent disengagement. The latch was a thin, spring-loaded metal strip which lay across the mouth of the hook. This unit presented an undesirable pressurized glove interface due to sharp edges which could cause excessive glove wear and possible glove failure.

It should be noted that the safety latching device tended to bind when attempting to disengage the hook and eye bolt.

.3.1.9 The OAP Alignment and Mounting Assembly

.3.1.9.1 Yoke - LM Shelter Mounting Interface - The OAP functional mockup simulated an alignment and mounting interface which was not representative of the actual hatch mount. It did, however, present a comparative base line from which to evaluate the gross task.

Four dowel pins were mounted in the circular base of the yoke (one dowel in each quadrant). These pins were aligned and inserted into mating holes in the simulated LM shelter roof. The horizontal and vertical alignment was accomplished using the derrick and the winch, and rotational positioning was accomplished manually.

This task required fine positional change capabilities on the part of the derrick and winch controls, a quality that the controls did not have.

Considerable difficulty was encountered in coordinating the horizontal, vertical, and rotational positioning of the yoke which resulted in rough handling of the yoke assembly during alignment and mounting. Four horizontally-oriented sliding bolt locks were used to maintain a rigid yoke to LM shelter mount. The bolts were positioned in each quadrant, and because of a vertical curved flange provided at the outer end of the bolt, could be easily engaged with the foot. This was not representative of the complex mechanical locking mechanism which would be provided for the actual OAP, but it did indicate an effective application of an adequate, simple mechanical locking device.

.3.1.9.2 Telescope-Yoke Mounting Interface - The telescope-yoke mounting consisted of large cylindrical posts on the telescope which were aligned and inserted into mating receptacles in the yoke. The horizontal, vertical, and rotational alignment and positioning problems encountered in the yoke-LM shelter mounting were again observed and the same problem evaluations apply.

.3.1.9.3 The OPA Mockup Guy Line - Both the OAP telescope and yoke assemblies included provisions for the attachment of guy lines. The primary purpose of the guy lines was

6.3.1.9.3 (Continued)

to provide the crewman in the lower area with a means of assisting in the control of the units during the hoisting sequence. A metal ring located on the lower edge of the unit provided a structural attach point for the guy line.

The guy lines were of little value because of the vertical orientation of the units relative to the crewman in the work area. During the hoisting sequence, contact between the units and the LM shelter could not be avoided. To be more effective, the horizontal component of the guy line path of action should be increased. In addition, it was considered a safety hazard to position the crewman underneath the unit while it was being raised.

6.3.1.10 The OAP Mockup Ladders - The ladders used in the OAP mission simulation were not considered part of the OAP functional mockup, but were incorporated by the Hamilton Standard personnel to provide a means of moving from the LM shelter descent stage storage area to the LM shelter roof work area. However, the ladders did provide a comparative human factors baseline to evaluate the mobility and clearance envelope for a pressure-suited crewman accomplishing a climbing task.

The vertically-oriented ladder did not incorporate any unique design features. It was constructed of 1.33-inch O.D. pipe which was welded to form vertical structural members and horizontal rungs. The vertical members functioned as the grip area and provided an adequate dimensional grip profile for a finger grip only. It would have been desirable to designate specific grasp areas and incorporate a grip profile which would be compatible with the semirigid palm restraint of the pressure glove. An example of this grip profile is shown in Paragraph 6.3.1.1.1, Design Criteria, Handles and Grasp Areas.

The dimensional profile of the ladder (step width 20 inches, step rise 11 inches) presented no specific restrictions or hazards for the pressure-suited crewman. Although this unit did not represent the optimum access device, sufficient fore-aft orientation of the torso was possible to minimize suit-ladder contact. This suit contact could be further diminished by reducing the required step-rise dimension.

6.3.1.11 The OAP Access Walkway - The access walkway used in the OAP functional mockup represented an approximation of available area, based upon existing LM mockups. The walkway was 15-3/4 inches wide, and required the pressure-suited crewman to side step around the periphery of the mockup because of the transverse swept volume of the pressure suit. No hand rails or hand holds were provided, and, it should be noted, the test subjects stepped off the walk several times during the performance of mission tasks. Hand rails would have optimized this walkway area and satisfied the safety requirement.

.3.1.11.1 Design Criteria, Walkways (Ref. A, B, MSFC-Std. 267A, Table 15) - A 15-3/4 inch walkway, such as provided in the LM shelter storage area, represented an adequate width for the pressure-suited crewman to walk by means of a side step, but the absence of a safety barrier and/or hand grips made this a hazardous task. Incorporation of hand holds or hand grips at approximately mid-chest height (range 46.4 inches at elbow level to 53.9 inches at nipple level) would provide an effective means of maintaining position and balance on a walkway. The addition of a radial-spoked frame and safety net, oriented approximately 60° above the horizontal, around walkways would also provide a safe working environment. The safety barrier should extend above the base of the walkway a minimum of shoulder height (59.9 inches).

.3.1.12 The LM Shelter Roof Work Area - The dimensional profile of the roof work area (length 77 inches, width 63 inches, including the simulated hatch area) provided sufficient area to complete all OAP pre-erection and deployment task requirements. With the OAP in the various stages of erection and deployment, available work space became a very critical factor in safely accomplishing the required tasks. With the OAP assembly in the deployed position, access to the limits of the work area was accomplished by rotating the entire assembly and moving around with it. This task is illustrated in figure 15. Because of the transverse swept volume of the pressure suit and the back pack, continuous contact was maintained with the OAP which was undesirable. Because of inadequate work space, a safety barrier was constructed on both sides of the work area. An effective safety barrier should be included as mission hardware to eliminate this crew hazard.

.3.1.13 Telescope Assembly Access Panels - The OAP functional mockup incorporated four access panels and three "black box" units within the telescope assembly. No functional identification or operational description of these units was available. Evaluation was limited to reach and accessibility provisions and unit removal and replacement.

.3.1.13.1 Access Panel Handles (Ref. A, B MSFC-Std-267A, Table 15) - Each of the access panels used a simple J-handle to open, close, and latch the door. Although these handles were not designed to accommodate the grip requirements of a pressurized glove, it was possible to achieve an adequate control grip. (See paragraph 6.3.1.1.1 for handle design criteria.) The handle was placed in a vertically oriented frontal plane with the open end of the handle facing upward in the closed and locked position. Actuation of the handle required the use of an inverted grip to apply a force of rotation. The heights of the access panels, when considered in terms of the reach and mobility requirements, were excessive and unacceptable.

To compensate for the excessive reach and mobility requirements, it was necessary to rotate the telescope assembly toward the crewman and directly into the work platform area, presenting a safety hazard as well as a work space restriction.

An acceptable range for vertical orientation of access panels would be between 46.4 inches, radial elbow height, and 53.9 inches, nipple height.

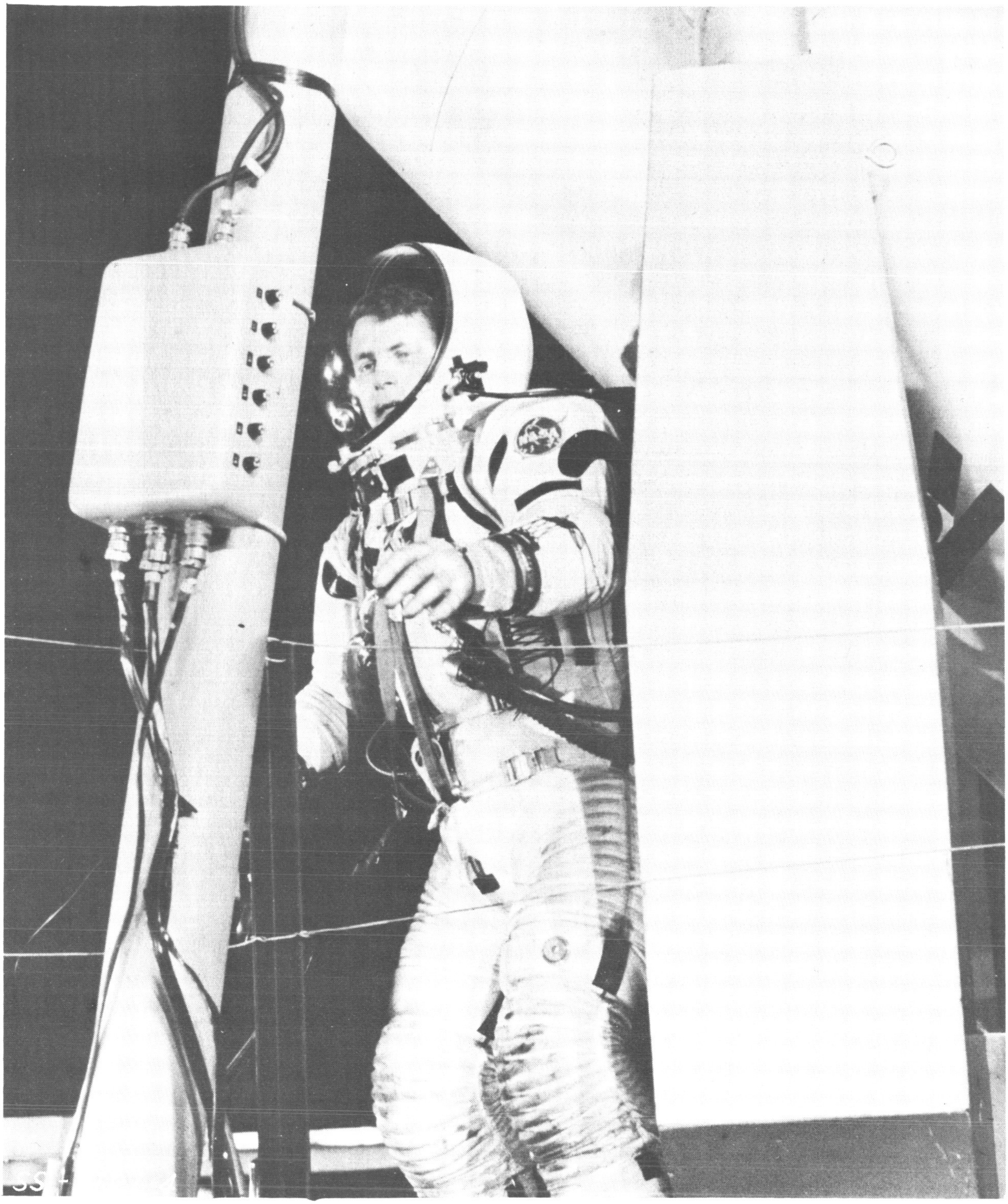


FIGURE 15

CREW SAFETY HAZARD, TEST SUBJECT ILLUSTRATING INADEQUATE WORK SPACE INCLUDING EQUIPMENT CONTACT AND LACK OF SAFETY BARRIER.

6.3.1.13.2 Large Access Panel - The dimensional profile of the large access panel was as follows:

- Vertical height of the access panel base above the work platform, 69 inches
- Vertical height of the access panel, 13-1/4 inches
- Effective horizontal width of the access panel, 21 inches
- External horizontal reach of the access panel, 10 inches
- Internal horizontal reach to crank handle of unit, 10 inches (maximum value)
- Crank handle
  Grip length, 3 inches
  Grip diameter, 5/8 inches
  Mounting base diameter, 3-7/8 inches (radius of action)

The crank handle provided a marginal pressure glove grip, and, when evaluated in terms of reach and mobility requirements, was less than adequate.

Removal and replacement of the unit was accomplished by rotating the crank handle 4-1/4 turns and guiding the unit over two alignment pins and the threaded locking shaft. This was an extremely awkward task for the pressurized suited crewman to accomplish. Relocation of the access panel as per the recommendations of paragraph 6.3.1.13.1 would improve the human performance.

6.3.1.13.3 Small Lower Access Panels - Two access panels with identical dimensional profiles, located directly opposite each other on the telescope assembly, provided access to the unit from either side. The dimensional profile of these small access panels was as follows:

- Vertical height of the access panel base above the work platform, 63-1/2 inches
- Vertical height of the access panel, 10-3/4 inches
- Effective horizontal width of the access panel, 9-3/8 inches
- External horizontal reach to the access panel, 10 inches
- Internal horizontal reach to the handle of the unit, 4-1/2 inches (maximum value)
- Internal vertical height of the handle relative to the compartment base, 5-1/2 inches
- Handle
  Grip palm width, 6-1/4 inches
  Grip palm thickness, 1-1/2 inches
  Grip cross sectional profile, height 5/8 inches, thickness 1/4 inch

The unit was mounted on horizontally oriented tracks, which provided a difficult mating task for the pressure-suited crewman. Human performance would be improved by relocating the access panel as per the recommendations of paragraph 6.3.1.13.1 and by incorporating a wide tapered entrance for the tracks.

.3.1.13.4 Small Upper Access Panel - The dimensional profile of the small upper access panel was as follows:

- Vertical height of the access panel base above the work platform, 74 inches
- Vertical height of the access panel, 9-1/2 inches
- Effective horizontal width of the access panel, 11-1/2 inches
- External horizontal reach to the access panel, 10 inches
- Internal horizontal reach to the handle, 16-1/4 inches
- Internal vertical height of the handle relative to the compartment base, 5-1/2 inches
- Handle (same dimensional profile as handle in 6.3.1.13.3.

The evaluation of paragraph 6.3.1.13.3 was also applicable to this access panel and unit.

.3.2 Man-Mission Interface

.3.2.1 Derrick Erection - The position A tasks consisted of the following:

- Establish a position within the limits of the LM shelter work area in order to effectively monitor and control the entire erection sequence.
- Maintain visual contact and voice communication with the crewman at position B during the entire erection sequence.
- The derrick was activated using the controls provided on the hand held control box. The derrick "extend" button and the winch "lower" button were used in sequence to continue erecting the derrick and positioning the spreader bar in the immediate storage area.
- If the spreader bar was not kept within the storage area during derrick erection, it became a safety hazard by freely swinging in close proximity to the position B crewman.
- The derrick was extended until the leg sections were completely engaged. The derrick erection was stopped at approximately the 45° above horizontal position.
- The A-frame leg locks were engaged.
- The erection sequence was then continued until the spreader bar was directly over the yoke.

The position B tasks consisted of the following:

- The crewman removed the spreader bar from its stowed position and held it captive until the winch and spreader bar were in position over the yoke.

(During the erection sequence the crew station (B) was directly beneath the derrick pivot mount and drive motor assembly. This presented a definite safety hazard.)

6.3.2.2 Yoke Assembly Deployment - The position A tasks consisted of the following:

- Using both the derrick and winch controls, the spreader bar and lift hooks were positioned directly over the yoke assembly lift points.
- The crewman then mounted the work platform and prepared to hoist the yoke assembly into the LM shelter roof work area.
- The winch "raise" control button was actuated, and the yoke assembly raised to the maximum height.
- The derrick "extend" control button was actuated, and the yoke assembly swung across the work area to a position over the mount.
- Using both derrick and winch controls in sequence, gross positioning of the assembly was accomplished prior to alignment and mounting.
- With the secondary crewman in the work area assisting with alignment, the yoke assembly was lowered into the mounted position. The winch hooks were removed from the yoke eye bolts, and the spreader bar assembly raised out of the work area. The reach requirements for the pressurized suited crewman (49 inches vertical, 24 inches horizontal) to disengage the lift hooks were acceptable.
- The spreader bar assembly was raised out of the work area as a safety precaution.

The position B tasks consisted of the following:

- Both winch hooks were engaged into the yoke eye bolts and the operation of the safety latching device verified. The yoke lift points were located at a point 69-1/2 inches above the work area base, which was an acceptable reach requirement for the pressure-suited crewman.
- In accomplishing this task, the crewman was required to move between the yoke assembly and the LM shelter structure to perform one of the hook-lift point connections. This was undesirable because of the suit-back pack contact with the mockup structure and the awkward position required of the crewman. If accessibility were provided from both sides of the storage area, this problem could have been eliminated.
- The guy line was attached to the yoke assembly. The crewman assisted in maintaining unit position and avoiding contact between the yoke assembly and the LM structure during ascent.
- After gross positioning of the yoke assembly had been accomplished at position A, the position B crewman ascended the ladder to the work area and prepared to assist with the alignment and mounting tasks.
- As it was lowered, the yoke assembly was hand positioned to ensure alignment of the dowel pins and the mating holes.
- After a rigid mount was secured, the yoke assembly was rotated to allow the position A crewman to disengage the lift hook safety locks and remove the lift hooks.
- The yoke assembly was rotated into position to receive the telescope assembly (parallel to the width of the work area).
- With the yoke assembly mounted in the deployed position, the available work space was divided into two separate areas, and the total effective work area was

6.3.2.2 (Continued)

reduced to approximately two-thirds of the original value. Passage from one side of the work area to the other was only possible by rotating the entire assembly. Without the use of a safety barrier at the edges of the work area, this would become a hazardous operation.
- The guy line was removed, and the position B crewman descended the ladder to the storage area.

6.3.2.3 Swing the Derrick Assembly into the Telescope Storage Area - The position A tasks consisted of the following:

- From a position on the work platform, the derrick "extend" control button was actuated. This moved the derrick assembly across the LM shelter roof until it reached its maximum point of travel directly over the telescope storage area.
- It should be noted that as the derrick moved into the telescope storage area one of the derrick A-frame legs was positioned across the work platform. It was possible to step onto the work platform extension and avoid equipment contact. It was also possible to continue the task from this position with no degradation of performance.

The position B tasks consisted of the following:

- The crewman moved from the yoke assembly storage area around the periphery of the LM structure descent stage into the telescope assembly storage area in order to assist with the deployment of this unit.

6.3.2.4 Telescope Assembly Deployment

The position A tasks consisted of the following:

- The derrick assembly was positioned directly above the telescope storage area. The spreader bar assembly was lowered into position over the telescope assembly by means of the winch "lower" control button.
- The crewman dismounted the work platform and descended the ladder to the telescope assembly storage area.
- The winch hook was engaged into the telescope eye bolt and the engagement of the safety latching device verified. The eye bolts were located at a point 61-1/2 inches above the work area base which was an acceptable reach requirement for the pressure-suited crewman.
- The crewman ascended the ladder to the roof work area, mounted the work platform, and prepared to raise the telescope assembly.
- The winch "raise" control button was activated and the telescope assembly raised to the upper limit of the winch.
- The derrick "retract" control button was activated and the telescope assembly swung into the roof work area to a position directly over the yoke.

6.3.2.4 (Continued)

- During this portion of the task, the most objectionable man-mission-equipment interface occurred. As the derrick and telescope assembly moved across the platform work area, the crewman was required to force his way between them in order to avoid being pushed off the work platform extension. The crewman was required to push the suspended telescope assembly approximately 12 to 18 inches away from the derrick leg to provide an adequate corridor to move back to the main work platform. From the standpoint of crew safety, this must be considered as grossly undesirable situation. This task is shown in figure 16.
- Using both derrick and winch controls in sequence, a gross positioning of the assembly was performed prior to final alignment and mounting.
- With the position B crewman in the work area to assist with alignment, the telescope assembly was lowered to engage the telescope mounting posts and the yoke receptacles.
- The winch hooks were removed from the telescope eye bolts with the assistance of the second crewman and the spreader bar assembly was raised out of the work area. The reach requirements for the pressure-suited crewman (63-1/2 inches vertical, 24 inches horizontal) were excessive.

The position B tasks consisted of the following:

- The winch hooks were attached to the telescope eye bolt, and engagement of the safety latching devices was verified.
- The guy line was attached to the telescope assembly. The crewman assisted in maintaining unit position and avoiding contact between the telescope assembly and the LM structure during the ascent.
- After gross positioning of the telescope assembly had been accomplished, the crewman ascended the ladder to the work area and prepared to assist with the alignment and mounting.
- The telescope assembly was manually positioned as it was lowered to ensure alignment of the telescope assembly mounting posts and yoke receptacles.
- After a rigid mount was secured, the OAP assembly was rotated to allow the position A crewman to disengage the safety locking device and remove the hooks. With the complete OAP assembly in the deployed position, effective work area was reduced to approximately one-third of the original area. Passage around the OAP assembly was only possible by rotating the entire assembly which placed the crewman at the extreme edge of the work area. Without a safety barrier at the edge of the work area, this became a hazardous operation. Passage around the OAP assembly is shown in figure 15.
- Passage between the OAP assembly, the work platform, and the derrick leg represented an extremely difficult task.
- The guy line was removed, and the position B crewman descended to the storage area.

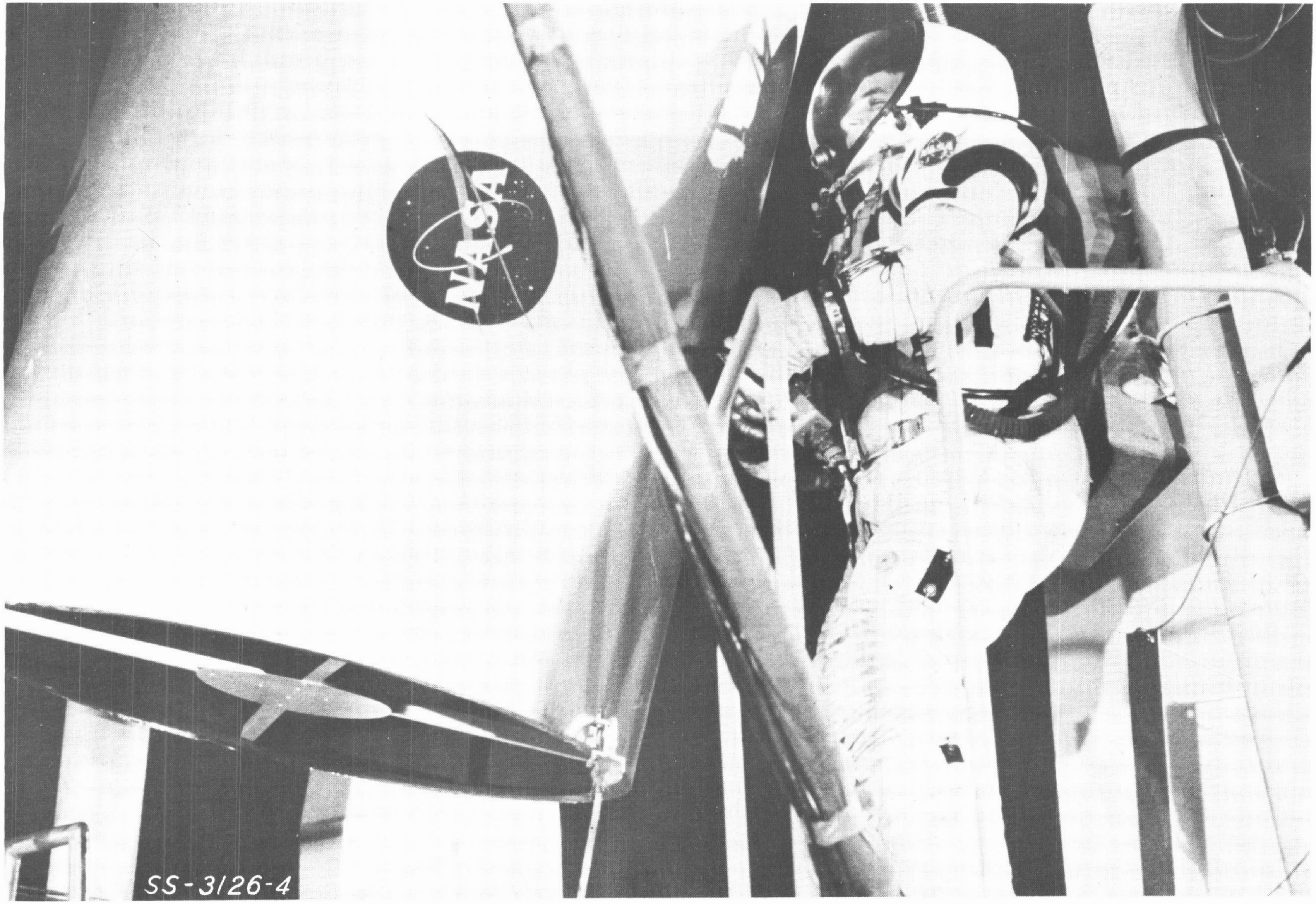


FIGURE 16

CREW SAFETY HAZARD, TEST SUBJECT FORCING HIS WAY BETWEEN THE TELESCOPE AND DERRICK ASSEMBLIES DURING THE DEPLOYMENT SEQUENCE.

6.3.2.5 Retract Derrick Assembly - Position A tasks consisted of the following:

- The derrick "retract" control button was actuated.
- The derrick assembly was stopped when it reached 45° above horizontal position, in order to release the derrick leg locks.
- The crewman dismounted the work platform and moved around the OAP.
- The A-frame leg locks were released and the derrick "retract" control button actuated to complete the derrick stowing sequence. This sequence was completed from the roof work area position above the storage area in order to maintain visual reference as well as voice communication with the second crewman.
- The derrick "retract" control button was released when the limit switch position was reached, and the control box was returned to its stowed position.

The position B tasks consisted of the following:

- This was primarily a station-keeping position which included stowing the spreader bar and monitoring the stowing of the derrick.

6.3.2.6 Gross Positioning of the OAP Assembly - The position A tasks consisted of the following: following:

- Each of the access panels was opened, and the "black box" unit removed, inspected, and returned to its functional position.
- The telescope was positioned in the horizontal reference plane to allow gross sighting through the eye-piece scope.
- The eye-piece scope did not represent an adequate design for the pressure-suited crewman. The close proximity to the main body of the OAP telescope made it impossible to obtain an adequate line of sight and resulted in helmet-visor contact with the OAP telescope.
- The crewman dismounted the work platform and descended the ladder to the storage area.
- With the telescope in the horizontal position, it was difficult to dismount from the work platform. The crewman was required to pass under the rear extreme of the telescope by bending over and stepping off the work platform at the edge of the LM shelter roof.

6.3.3 Component Evaluation Summary

A summary of the human engineering evaluation of the components of OAP functional mockup is contained in figure 17. This summary highlights the features of the OAP mockup as determined during the human factors evaluation, rather than the recommended design criteria. The complete discussion of these components and the recommended design criteria can be found in the appropriate paragraphs referenced in the evaluation summary.

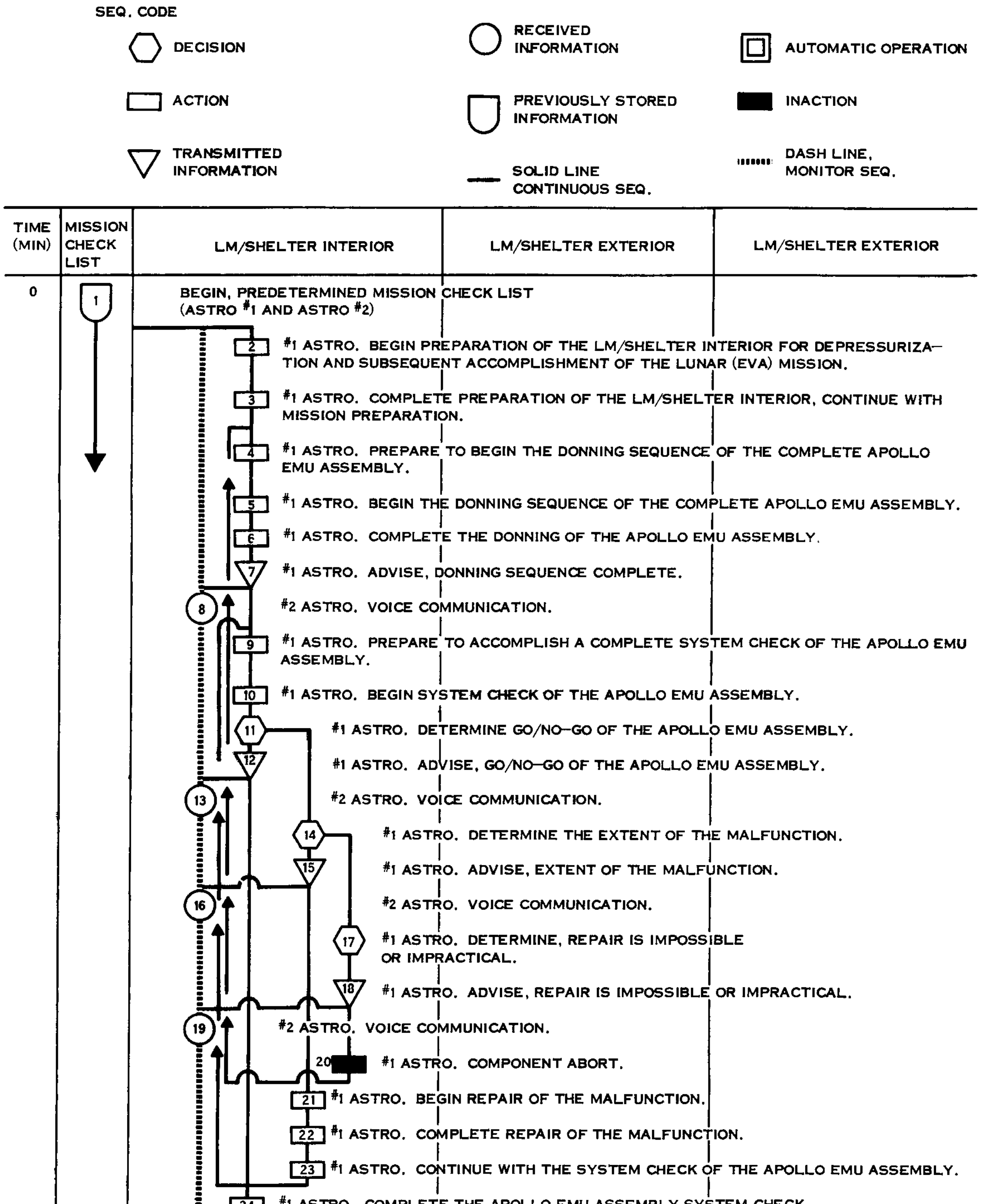
WORK AREA	TEXT REFERENCE PARAGRAPH	PERSONNEL HAZARD		ACCESSIBILITY		DIMENSION*		OBSTRUCTED MOVEMENT		COLOR CODING		GUARDED OR SHIELDED		LABEL CODING		REMARKS
		YES	NO	ACCEPT.	NOT ACCEPT.	ACCEPT.	NOT ACCEPT.	YES	NO	YES	NO	YES	NO	YES	NO	
LM ROOF	6.3.1.12	X			X	X		X		N/A		N/A		N/A		THIS EVALUATION IS BASED UPON THE REDUCTION OF EFFECTIVE WORK AREA RESULTING FROM DERRICK AND CAP DEPLOYMENT
PLATFORM, EXT.	6.3.1.7	X			X	X		X		N/A		N/A		N/A		
STORAGE		X			X	X		X		N/A		N/A		N/A		
CONTROL BOX	6.3.1.1		X	X		X				N/A		N/A		N/A		
HANDLE	6.3.1.1.1		X	X			X	X		N/A		N/A		N/A		
PUSHBUTTON	6.3.1.2		X	X		X		X		X			X		X	CODED FOR VISUAL REF. RATHER THAN FUNCTION ACCEPTABLE FOR A SINGLE WARNING DISPLAY ONLY
WARNING LT.	6.3.1.3		X	N/A		N/A		N/A		X		N/A			X	
ELEC. CABLE	6.3.1.4	X		N/A		N/A		N/A			X	N/A		N/A		
WALKWAY	6.3.1.11	X		X		X			X	N/A		N/A		N/A		DIMENSIONALLY ACCEPTABLE FOR A SIDE STEP ONLY.
ACCESS PANEL	6.3.1.13	X			X		X	X		N/A		N/A			X	
DERRICK ASSY. LATCHES	6.3.1.6	X		X			X	N/A		N/A			X	N/A		
ELEC. CONN.	6.3.1.4		X	N/A			X	N/A			X	N/A			X	
FUSES	6.3.1.5		X		X		X	N/A			X	N/A			X	
ELEC. TERMINAL BOX	6.3.1.5	X			X	N/A		X		N/A		N/A			X	
WINCH LIFT HOOKS	6.3.1.8	X		X		X			X	N/A		X		N/A		

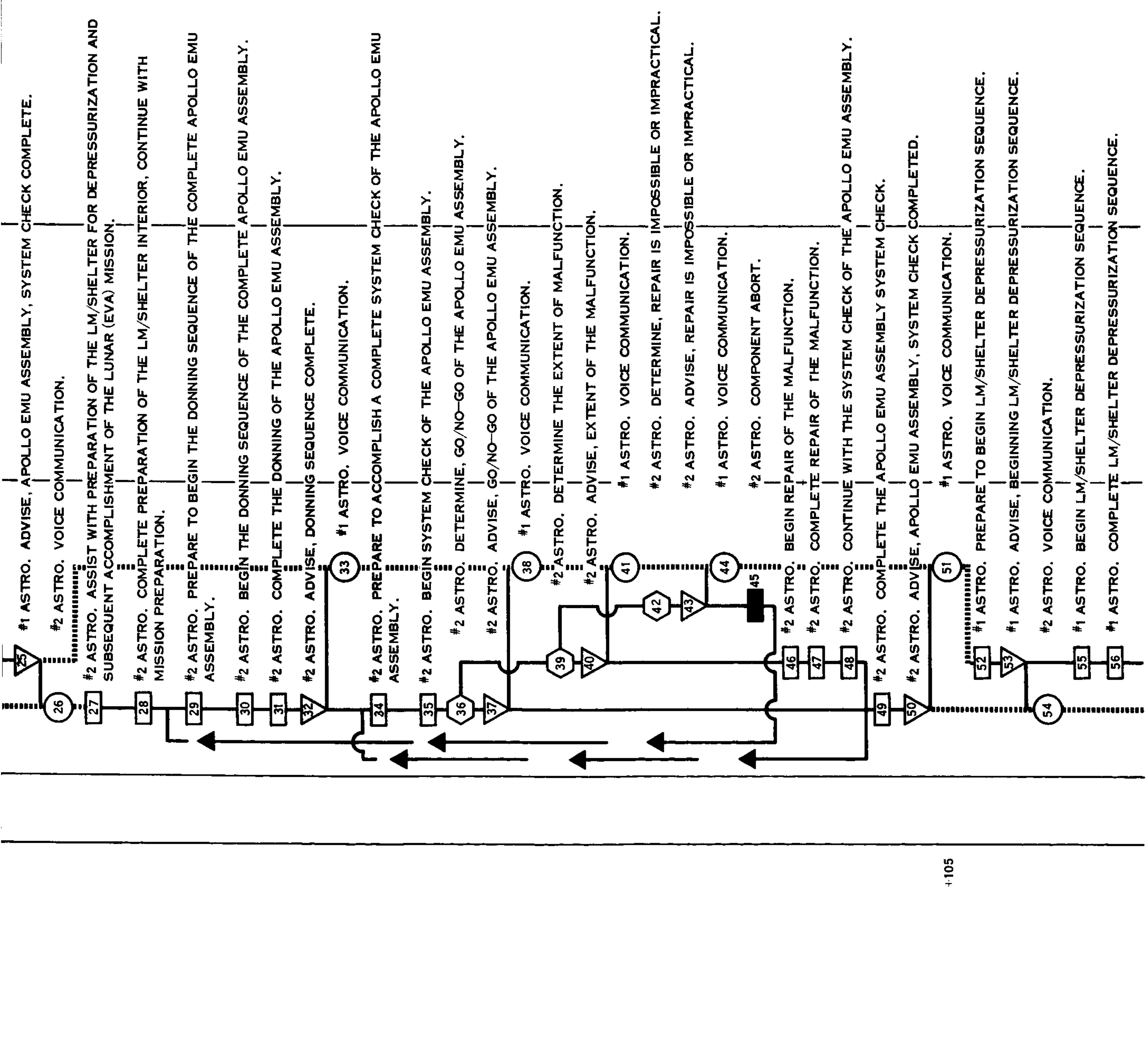
NOTE: N/A SPECIFIC CRITERIA NOT APPLICABLE

*DIM. WITH DIRECT ANTHROPOMETRIC ASSOCIATION

FIGURE 17. HUMAN ENGINEERING EVALUATION SUMMARY OAP MOCKUP

APPENDIX A


SEQ. CODE
DECISION
ACTION
TRANSMITTED INFORMATION
RECEIVED INFORMATION
PREVIOUSLY STORED INFORMATION
SOLID LINE CONTINUOUS SEQ.
AUTOMATIC OPERATION
INACTION
DASH LINE, MONITOR SEQ.
TIME (MIN)
MISSION CHECK LIST
LM/SHELTER INTERIOR
LM/SHELTER EXTERIOR
LM/SHELTER EXTERIOR
0
1
BEGIN, PREDETERMINED MISSION CHECK LIST (ASTRO #1 AND ASTRO #2)
2 #1 ASTRO. BEGIN PREPARATION OF THE LM/SHELTER INTERIOR FOR DEPRESSURIZATION AND SUBSEQUENT ACCOMPLISHMENT OF THE LUNAR (EVA) MISSION.
3 #1 ASTRO. COMPLETE PREPARATION OF THE LM/SHELTER INTERIOR, CONTINUE WITH MISSION PREPARATION.
4 #1 ASTRO. PREPARE TO BEGIN THE DONNING SEQUENCE OF THE COMPLETE APOLLO EMU ASSEMBLY.
5 #1 ASTRO. BEGIN THE DONNING SEQUENCE OF THE COMPLETE APOLLO EMU ASSEMBLY.
6 #1 ASTRO. COMPLETE THE DONNING OF THE APOLLO EMU ASSEMBLY.
7 #1 ASTRO. ADVISE, DONNING SEQUENCE COMPLETE.
8 #2 ASTRO. VOICE COMMUNICATION.
9 #1 ASTRO. PREPARE TO ACCOMPLISH A COMPLETE SYSTEM CHECK OF THE APOLLO EMU ASSEMBLY.
10 #1 ASTRO. BEGIN SYSTEM CHECK OF THE APOLLO EMU ASSEMBLY.
11 #1 ASTRO. DETERMINE GO/NO-GO OF THE APOLLO EMU ASSEMBLY.
12 #1 ASTRO. ADVISE, GO/NO-GO OF THE APOLLO EMU ASSEMBLY.
13 #2 ASTRO. VOICE COMMUNICATION.
14 #1 ASTRO. DETERMINE THE EXTENT OF THE MALFUNCTION.
15 #1 ASTRO. ADVISE, EXTENT OF THE MALFUNCTION.
16 #2 ASTRO. VOICE COMMUNICATION.
17 #1 ASTRO. DETERMINE, REPAIR IS IMPOSSIBLE OR IMPRACTICAL.
18 #1 ASTRO. ADVISE, REPAIR IS IMPOSSIBLE OR IMPRACTICAL.
19 #2 ASTRO. VOICE COMMUNICATION.
20 #1 ASTRO. COMPONENT ABORT.
21 #1 ASTRO. BEGIN REPAIR OF THE MALFUNCTION.
22 #1 ASTRO. COMPLETE REPAIR OF THE MALFUNCTION.
23 #1 ASTRO. CONTINUE WITH THE SYSTEM CHECK OF THE APOLLO EMU ASSEMBLY.
24 #1 ASTRO. COMPLETE THE APOLLO EMU ASSEMBLY SYSTEM CHECK



TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.

A-2

57 #1 ASTRO. ADVISE LM/SHELTER DEPRESSURIZATION SEQUENCE COMPLETE.

+111 58 #2 ASTRO. VOICE COMMUNICATION.

59 #1 ASTRO. PREPARE TO OPEN LM/SHELTER EXTERNA ROOF HATCH.

60 #1 ASTRO. ADVISE, PREPARE FOR LM/SHELTER EXTERNAL ROOF HATCH OPENING.

61 #2 ASTRO. VOICE COMMUNICATIONS.

+114 62 #1 ASTRO. OPEN LM/SHELTER EXTERNAL ROOF HATCH

63 #1 ASTRO. PREPARE TO EGRESS LM/SHELTER THROUGH EXTERNAL ROOF HATCH

64 #1 ASTRO. ADVISE, PREPARING TO EGRESS LM/SHELTER.

+121 65 #2 ASTRO. VOICE COMMUNICATION.

66 #1 ASTRO. EGRESS LM/SHELTER AND BEGIN PREPARATION OF ROOF HATCH FOR YOKE MOUNTING.

67 #1 ASTRO. CONTINUE PREPARATION OF ROOF HATCH FOR YOKE MOUNTING.

68 #1 ASTRO. COMPLETE PREPARATION OF ROOF HATCH FOR YOKE MOUNTING.

69 #1 ASTRO. ADVISE PREPARATION OF ROOF HATCH COMPLETED.

70 #2 ASTRO. VOICE COMMUNICATION.

71 #1 ASTRO. BEGIN PREPARATION OF WORK PLATFORM MOUNTING AREA, WHILE AWAITING ARRIVAL OF #2 ASTRO.

72 #2 ASTRO. PREPARE TO EGRESS LM/SHELTER THROUGH EXTERNAL SIDE HATCH.

73 #2 ASTRO. ADVISE, PREPARING TO EGRESS LM/SHELTER THROUGH EXTERNAL SIDE HATCH.

74 #1 ASTRO. VOICE COMMUNICATION

75 #2 ASTRO. EGRESS LM/SHELTER THROUGH EXTERNAL SIDE HATCH AT THE LM DESCENT STAGE LEVEL.

+125 76 #2 ASTRO. COMPLETE EGRESS SEQUENCE. BEGIN MOVING AROUND DESCENT STAGE LEVEL TO STORAGE AREA.

77 #2 ASTRO. ARRIVE AT DESCENT STAGE STORAGE AREA.

78 #2 ASTRO. ADVISE ARRIVAL AT DESCENT STAGE STORAGE AREA.

79 #1 ASTRO. VOICE COMMUNICATION.

80 #2 ASTRO. REMOVE WORK PLATFORM FROM THE LM/DESCENT STAGE STORAGE POSITION.

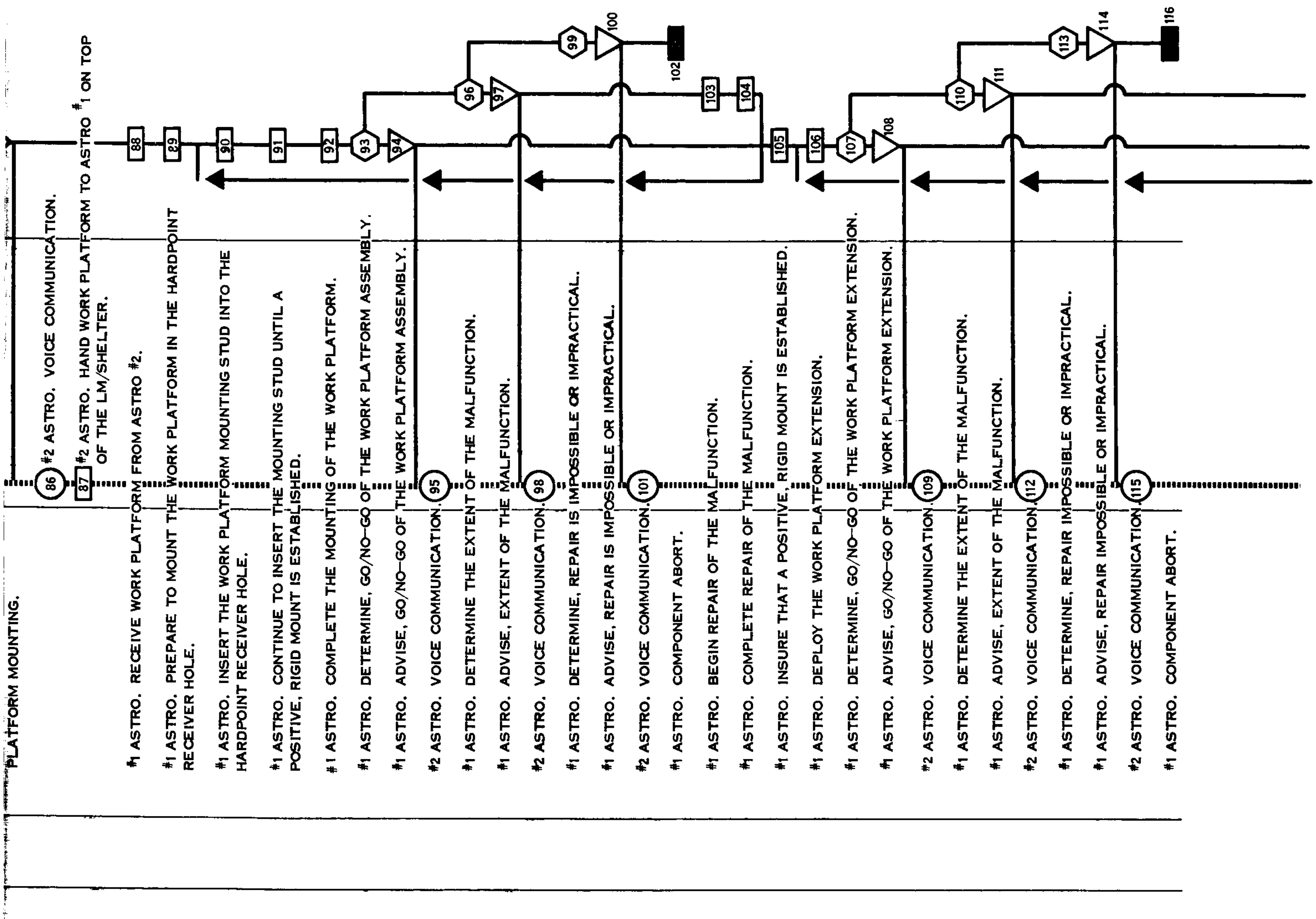
81 #2 ASTRO. PREPARE TO HAND WORK PLATFORM TO ASTRO #1 ON TOP OF THE LM/SHELTER ROOF.

82 #2 ASTRO. ADVISE, WORK PLATFORM READY FOR TRANSFER TO LM/SHELTER ROOF.

83 #1 ASTRO. VOICE COMMUNICATION.

84 #1 ASTRO. COMPLETE PREPARATION OF THE WORK PLATFORM MOUNTING AREA.

85 #1 ASTRO. ADVISE, WORK PLATFORM MOUNTING AREA IS READY FOR



TIME LINE ANALYSIS FOR LUNAR SURFACE

EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.

A-4

+140

117 #1 ASTRO. RETURN THE EXTENSION TO THE STORED POSITION.

118 #1 ASTRO. BEGIN REPAIR OF MALFUNCTION.

119 #1 ASTRO. COMPLETE REPAIR OF THE MALFUNCTION.

120 #2 ASTRO. PREPARE TO REMOVE THE RESTRAINT STORAGE STRAPS FROM THE DERRICK.

121 #2 ASTRO. BEGIN REMOVAL OF ALL THE RESTRAINT STORAGE STRAPS FROM THE DERRICK.

122 #2 ASTRO. CONTINUE WITH THE REMOVAL OF THE RESTRAINT STRAPS IN PREPARATION FOR ERECTION OF THE DERRICK ASSEMBLY.

123 #1 ASTRO. PREPARE TO REMOVE THE DERRICK CABLE CONTROL BOX FROM ITS STORED POSITION.

124 #1 ASTRO. REMOVE THE DERRICK CABLE CONTROL BOX FROM ITS STORED POSITION.

125 #1 ASTRO. PREPARE TO ACTIVATE THE DERRICK "EXTEND" CONTROL BUTTON AND OBSERVE DEPLOYMENT SEQUENCE.

126 #2 ASTRO. COMPLETE THE REMOVAL OF ALL THE RESTRAINT STRAPS FROM THE DERRICK ASSEMBLY.

127 #2 ASTRO. ADVISE ALL RESTRAINT STRAPS ARE REMOVED, DERRICK IS CLEAR FOR ERECTION.

128 #1 ASTRO. VOICE COMMUNICATION.

129 #1 ASTRO. ACTIVATE THE DERRICK "EXTEND" CONTROL BUTTON.

130 #1 ASTRO. OBSERVE THE DEPLOYMENT SEQUENCE.

131 #2 ASTRO. OBSERVE THE DEPLOYMENT SEQUENCE.

132 #1 ASTRO. DETERMINE, GO/NO-GO OF THE DERRICK EXTENSION ASSEMBLY.

133 #1 ASTRO. ADVISE, GO/NO-GO OF THE DERRICK EXTENSION ASSEMBLY.

134 #2 ASTRO. VOICE COMMUNICATION.

135 #1 ASTRO. DETERMINE THE EXTENT OF THE MALFUNCTION.

136 #1 ASTRO. ADVISE, THE EXTENT OF THE MALFUNCTION.

137 #2 ASTRO. VOICE COMMUNICATION.

138 #1 ASTRO. DETERMINE, REPAIR IMPOSSIBLE OR IMPRACTICAL.

139 #1 ASTRO. ADVISE REPAIR IMPOSSIBLE OR IMPRACTICAL.

140 #2 ASTRO. VOICE COMMUNICATION.

141 #1 ASTRO. MISSION ABORT.

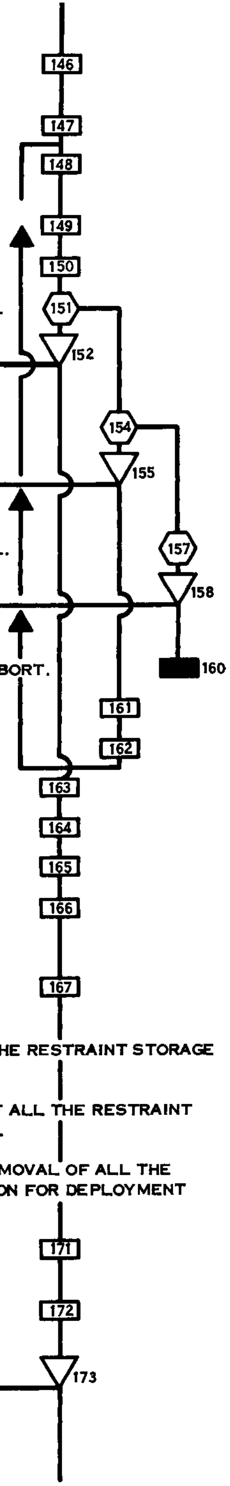
142 #1 ASTRO. BEGIN REPAIR OF THE MALFUNCTION.

143 #2 ASTRO. ASSIST WITH THE REPAIR OF THE MALFUNCTION.

144 #1 ASTRO. COMPLETE REPAIR OF THE MALFUNCTION.

145 #1 ASTRO. CONTINUE TO EXTEND THE DERRICK UNTIL THE "A" FRAME

LEGS ARE COMPLETELY ENGAGED, AND HAVE BEEN RAISE TO APPROX. THE 45° ABOVE HORIZONTAL POSITION.



146 #1 ASTRO. PREPARE TO STOP THE DERRICK IN THE 45° ABOVE HORIZONTAL POSITION TO ENGAGE THE MECHANICAL LOCKS.

147 #1 ASTRO. RELEASE "EXTEND" BUTTON.

148 #1 ASTRO. OBSERVE THAT THE LEG ASSEMBLY AT EACH JOINT IS COMPLETELY ENGAGED.

149 #1 ASTRO. ENGAGE THE LOCKING DEVICE (3 LOCKS – EACH LEG).

150 #1 ASTRO. SECURE THE LOCKS (EACH LEG)

151 #1 ASTRO. DETERMINE, GO/NO–GO OF THE DERRICK LOCKING ASSEMBLIES.

152 #1 ASTRO. ADVISE, GO/NO–GO OF THE DERRICK LOCKING ASSEMBLIES.

153 #2 ASTRO. VOICE COMMUNICATION.

154 #1 ASTRO. DETERMINE, THE EXTENT OF THE MALFUNCTION.

155 #1 ASTRO. ADVISE, EXTENT OF THE MALFUNCTION.

156 #2 ASTRO. VOICE COMMUNICATION.

157 #1 ASTRO. DETERMINE, REPAIR IMPOSSIBLE OR IMPRACTICAL.

158 #1 ASTRO. ADVISE, REPAIR IMPOSSIBLE OR IMPRACTICAL.

159 #2 ASTRO. VOICE COMMUNICATION.

160 #1 ASTRO. MISSION ABORT.

161 #1 ASTRO. BEGIN REPAIR OF THE MALFUNCTION.

162 #1 ASTRO. COMPLETE REPAIR OF THE MALFUNCTION.

163 #1 ASTRO. PREPARE TO CONTINUE WITH THE ERECTION OF THE DERRICK.

164 #1 ASTRO. ACTIVATE THE DERRICK "EXTEND" CONTROL BUTTON.

165 #1 ASTRO. OBSERVE THE DEPLOYMENT SEQUENCE.

166 #1 ASTRO. CONTINUE TO DEPLOY THE DERRICK UNTIL IT REACHES THE FULLY DEPLOYED POSITION, AND BE PREPARED TO STOP THE SEQUENCE WHEN IT REACHES THIS POINT.

+170

167 #1 ASTRO. RELEASE "EXTEND" CONTROL BUTTON, PREPARE TO STEP UP ONTO THE WORK PLATFORM.

168 #2 ASTRO. PREPARE TO REMOVE THE RESTRAINT STORAGE STRAPS FROM THE YOKE.

169 #2 ASTRO. BEGIN THE REMOVAL OF ALL THE RESTRAINT STORAGE STRAPS FROM THE YOKE.

170 #2 ASTRO. CONTINUE WITH THE REMOVAL OF ALL THE RESTRAINT STRAPS IN PREPARATION FOR DEPLOYMENT OF THE YOKE.

171 #1 ASTRO. STEP UP ONTO THE WORK PLATFORM AND PREPARE TO POSITION THE DERRICK AND SPREADER BAR.

172 #1 ASTRO. BEGIN POSITIONING OF DERRICK AND SPREADER BAR, USING EXTEND AND RAISE BUTTON.

173 #1 ASTRO. ADVISE DERRICK AND SPREADER BAR ARE BEING POSITIONED.

TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.

174 #2 ASTRO. VOICE COMMUNICATION.

175 #2 ASTRO. COMPLETE THE REMOVAL OF ALL OF THE RESTRAINT STORAGE STRAPS FROM THE YOKE.

176 #2 ASTRO. ADVISE THE REMOVAL OF ALL THE RESTRAINT STORAGE STRAPS IS COMPLETED.

177 #1 ASTRO. VOICE COMMUNICATION.

178 #2 ASTRO. PREPARE TO RIG A GUIDELINE TO THE YOKE TO ASSIST IN STABILIZING THE YOKE WHILE IT IS BEING RAISED INTO POSITION.

179 #2 ASTRO. COMPLETE THE ATTACHMENT OF THE GUIDELINE.

180 #2 ASTRO. ADVISE, GUIDELINE ATTACHED.

181 #1 ASTRO. VOICE COMMUNICATION.

182 #1 ASTRO. CONTINUE POSITIONING DERRICK AND SPREADER BAR UNTIL THE SPREADER BAR IS IN POSITION OVER THE YOKE LIFT POINTS.

183 #2 ASTRO. OBSERVE, SPREADER BAR IS IN POSITION OVER THE YOKE LIFT POINTS.

184 #2 ASTRO. ADVISE SPREADER BAR IS IN POSITION OVER THE YOKE LIFT POINTS.

185 #2 ASTRO. VOICE COMMUNICATION.

186 #1 ASTRO. PREPARE TO STOP THE SPREADER BAR ASSEMBLY.

187 #1 ASTRO. RELEASE "LOWER" CONTROL BUTTON.

188 #2 ASTRO. PREPARE TO ATTACH THE HOIST LINES TO THE YOKE ATTACH POINTS.

189 #2 ASTRO. ATTACH HOIST LINES TO THE YOKE ATTACH POINTS.

190 #2 ASTRO. ADVISE, HOIST LINE ATTACHMENTS COMPLETED.

191 #1 ASTRO. VOICE COMMUNICATION.

192 #1 ASTRO. PREPARE TO RAISE THE YOKE USING THE "RAISE" CONTROL BUTTON.

193 #1 ASTRO. ACTIVATE "RAISE" CONTROL BUTTON.

194 #2 ASTRO. DETERMINE, GO/NO–GO OF THE HOIST ASSEMBLY.

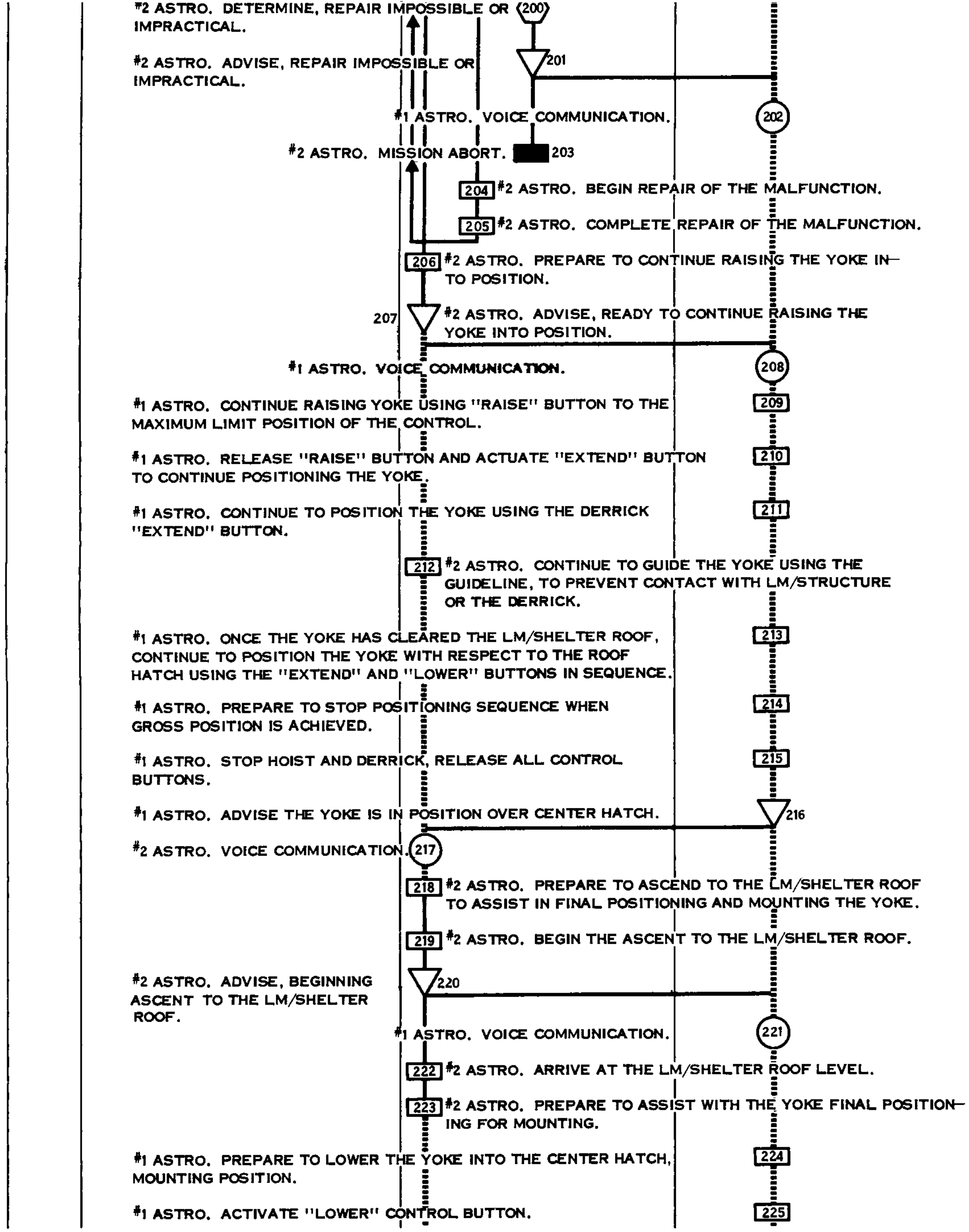
195 #2 ASTRO. ADVISE GO/NO–GO OF THE HOIST ASSEMBLY.

196 #1 ASTRO. VOICE COMMUNICATION.

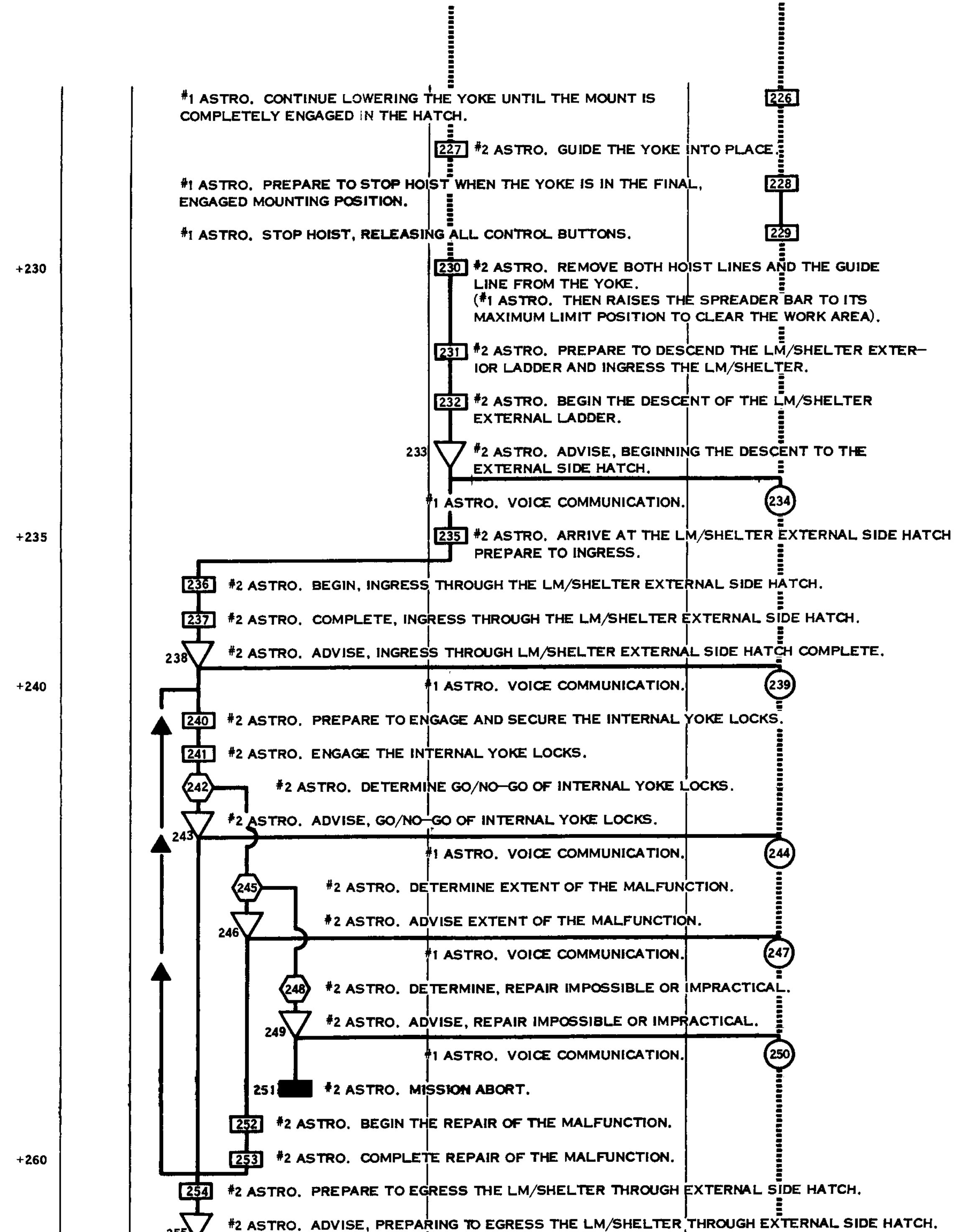
197 #2 ASTRO. DETERMINE THE EXTENT OF THE MALFUNCTION.

198 #2 ASTRO. ADVISE EXTENT OF THE MALFUNCTION.

199 #1 ASTRO. VOICE COMMUNICATION.



TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.


226 #1 ASTRO. CONTINUE LOWERING THE YOKE UNTIL THE MOUNT IS COMPLETELY ENGAGED IN THE HATCH.
227 #2 ASTRO. GUIDE THE YOKE INTO PLACE.
228 #1 ASTRO. PREPARE TO STOP HOIST WHEN THE YOKE IS IN THE FINAL, ENGAGED MOUNTING POSITION.
229 #1 ASTRO. STOP HOIST, RELEASING ALL CONTROL BUTTONS.
+230
230 #2 ASTRO. REMOVE BOTH HOIST LINES AND THE GUIDE LINE FROM THE YOKE. (#1 ASTRO. THEN RAISES THE SPREADER BAR TO ITS MAXIMUM LIMIT POSITION TO CLEAR THE WORK AREA).
231 #2 ASTRO. PREPARE TO DESCEND THE LM/SHELTER EXTER–IOR LADDER AND INGRESS THE LM/SHELTER.
232 #2 ASTRO. BEGIN THE DESCENT OF THE LM/SHELTER EXTERNAL LADDER.
233 #2 ASTRO. ADVISE, BEGINNING THE DESCENT TO THE EXTERNAL SIDE HATCH.
234 #1 ASTRO. VOICE COMMUNICATION.
+235
235 #2 ASTRO. ARRIVE AT THE LM/SHELTER EXTERNAL SIDE HATCH PREPARE TO INGRESS.
236 #2 ASTRO. BEGIN, INGRESS THROUGH THE LM/SHELTER EXTERNAL SIDE HATCH.
237 #2 ASTRO. COMPLETE, INGRESS THROUGH THE LM/SHELTER EXTERNAL SIDE HATCH.
238 #2 ASTRO. ADVISE, INGRESS THROUGH LM/SHELTER EXTERNAL SIDE HATCH COMPLETE.
+240
239 #1 ASTRO. VOICE COMMUNICATION.
240 #2 ASTRO. PREPARE TO ENGAGE AND SECURE THE INTERNAL YOKE LOCKS.
241 #2 ASTRO. ENGAGE THE INTERNAL YOKE LOCKS.
242 #2 ASTRO. DETERMINE GO/NO–GO OF INTERNAL YOKE LOCKS.
243 #2 ASTRO. ADVISE, GO/NO–GO OF INTERNAL YOKE LOCKS.
244 #1 ASTRO. VOICE COMMUNICATION.
245 #2 ASTRO. DETERMINE EXTENT OF THE MALFUNCTION.
246 #2 ASTRO. ADVISE EXTENT OF THE MALFUNCTION.
247 #1 ASTRO. VOICE COMMUNICATION.
248 #2 ASTRO. DETERMINE, REPAIR IMPOSSIBLE OR IMPRACTICAL.
249 #2 ASTRO. ADVISE, REPAIR IMPOSSIBLE OR IMPRACTICAL.
250 #1 ASTRO. VOICE COMMUNICATION.
251 #2 ASTRO. MISSION ABORT.
252 #2 ASTRO. BEGIN THE REPAIR OF THE MALFUNCTION.
+260
253 #2 ASTRO. COMPLETE REPAIR OF THE MALFUNCTION.
254 #2 ASTRO. PREPARE TO EGRESS THE LM/SHELTER THROUGH EXTERNAL SIDE HATCH.
#2 ASTRO. ADVISE, PREPARING TO EGRESS THE LM/SHELTER THROUGH EXTERNAL SIDE HATCH.

+265

(256) #1 ASTRO. VOICE COMMUNICATION.

[257] #2 ASTRO. EGRESS LM/SHELTER THROUGH THE EXTERNAL SIDE HATCH AND MOVE AROUND THE DESCENT STAGE LEVEL TO THE TELESCOPE STORAGE AREA.

[258] #2 ASTRO. CONTINUE AROUND DESCENT STAGE TO THE TELESCOPE STORAGE AREA.

[259] #2 ASTRO. ARRIVE TELESCOPE STORAGE AREA BEGIN INSPECTION OF TELESCOPE ASSEMBLY.

260 #2 ASTRO. ADVISE ARRIVE AT TELESCOPE STORAGE AREA.

(261) #1 ASTRO. VOICE COMMUNICATION.

[262] #2 ASTRO. PREPARE TO REMOVE THE RESTRAINT STORAGE STRAPS FROM THE TELESCOPE.

[263] #2 ASTRO. BEGIN THE REMOVAL OF ALL THE RESTRAINT STORAGE STRAPS FROM THE TELESCOPE.

[264] #2 ASTRO. CONTINUE WITH THE REMOVAL OF THE RESTRAINT STRAPS IN PREPARATION FOR DEPLOYMENT OF THE TELE–SCOPE.

[265] #1 ASTRO. PREPARE TO SWING THE DERRICK OVER THE TOP OF THE LM/SHELTER TO THE TELESCOPE STORAGE AREA.

[266] #1 ASTRO. BEGIN THE SEQUENCE OF SWINGING THE DERRICK OVER THE LM/SHELTER ROOF,USING THE DERRICK "EXTEND" BUTTON.

[267] #1 ASTRO. CONTINUE THE SEQUENCE OF SWINGING THE DERRICK OVER THE LM/SHELTER ROOF.

[268] #1 ASTRO. COMPLETE THE POSITIONING OF THE DERRICK AND RELEASE THE "EXTEND" BUTTON WHEN THE LIMITING POSITION IS REACHED.

269 #1 ASTRO. ADVISE, DERRICK IS IN POSITION FOR TELESCOPE DEPLOY–MENT.

(270) #2 ASTRO. VOICE COMMUNICATION.

[271] #2 ASTRO. COMPLETE THE REMOVAL OF ALL THE RESTRAINT STORAGE STRAPS FROM THE TELESCOPE.

272 #2 ASTRO. ADVISE, REMOVAL OF ALL THE RESTRAINT STORAGE STRAPS IS COMPLETED.

(273) #1 ASTRO. VOICE COMMUNICATION.

[274] #2 ASTRO. PREPARE TO RIG A GUIDELINE TO THE TELE–SCOPE TO ASSIST IN STABILIZING THE TELESCOPE WHILE IT IS BEING RAISED INTO POSITION.

[275] #2 ASTRO. COMPLETE THE ATTACHMENT OF THE GUIDELINE.

276 #2 ASTRO. ADVISE, GUIDELINE ATTACHMENT COMPLETE.

(277) #1 ASTRO. VOICE COMMUNICATION.

[278] #1 ASTRO. PREPARE TO LOWER THE SPREADER BAR, USING THE "LOWER" CONTROL BUTTON.

[279] #1 ASTRO. ACTIVATE "LOWER" CONTROL BUTTON.

280 #1 ASTRO. ADVISE, THE SPREADER BAR ASSEMBLY IS BEING LOWERED.

(281) #2 ASTRO. VOICE COMMUNICATION

TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.

A-10

282 #1 ASTRO. CONTINUE LOWERING THE SPREADER BAR ASSEMBLY UNTIL IT IS IN POSITION OVER THE TELESCOPE LIFT POINTS.

283 #2 ASTRO. OBSERVE THAT THE SPREADER BAR IS IN POSITION OVER THE TELESCOPE LIFT POINTS.

284 #2 ASTRO. ADVISE, SPREADER BAR IS IN POSITION OVER THE TELESCOPE LIFT POINTS.

285 #1 ASTRO. VOICE COMMUNICATION.

286 #1 ASTRO. PREPARE TO STOP THE SPREADER BAR ASSEMBLY.

287 #1 ASTRO. RELEASE "LOWER" CONTROL BUTTON.

288 #2 ASTRO. PREPARE TO ATTACH THE HOIST LINE TO THE TELESCOPE LIFT POINT (NEAR SIDE OF THE TELESCOPE).

289 #2 ASTRO. ATTACH THE HOIST LINE.

290 #2 ASTRO. ADVISE, HOIST LINE ATTACHMENT IS COMPLETED.

291 #1 ASTRO. VOICE COMMUNICATION.

292 #1 ASTRO. PREPARE TO DISMOUNT FROM THE WORK PLATFORM TO AID IN CONNECTING THE HOIST LINES.

293 #1 ASTRO. DISMOUNT FROM THE WORK PLATFORM AND PREPARE TO DESCEND EXTERIOR LADDER TO TELESCOPE STORAGE AREA.

294 #1 ASTRO. DESCEND EXTERIOR LADDER TO THE TELESCOPE STORAGE AREA.

295 #1 ASTRO. ARRIVE AT THE TELESCOPE STORAGE AREA AND PREPARE TO ATTACH THE HOIST LINE TO THE TELESCOPE LIFT POINT (FAR SIDE OF TELESCOPE).

296 #1 ASTRO. ATTACH THE HOIST LINE.

297 #1 ASTRO. ADVISE HOIST LINE ATTACHMENT IS COMPLETED.

298 #2 ASTRO. VOICE COMMUNICATION.

299 #1 ASTRO. PREPARE TO ASCEND THE EXTERIOR LADDER TO THE LM/SHELTER ROOF.

300 #1 ASTRO. ASCEND LM/SHELTER EXTERIOR LADDER.

301 #1 ASTRO. ARRIVE AT LM/SHELTER ROOF AND PREPARE TO MOUNT WORK PLATFORM.

302 #1 ASTRO. MOUNT WORK PLATFORM AND PREPARE TO CONTINUE TELESCOPE ERECTION SEQUENCE.

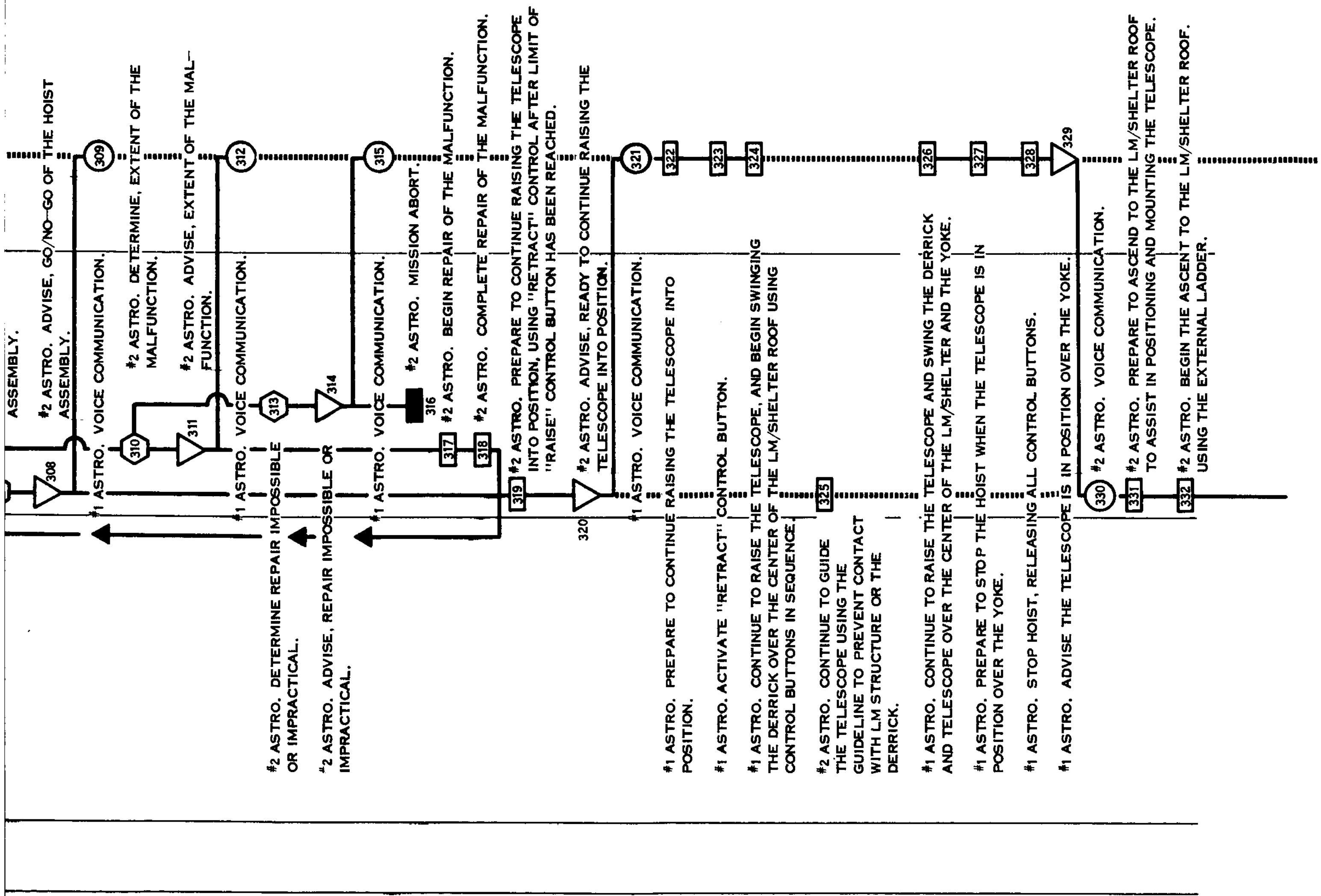
303 #1 ASTRO. ADVISE, PREPARE TO CONTINUE MISSION.

304 #2 ASTRO. VOICE COMMUNICATION.

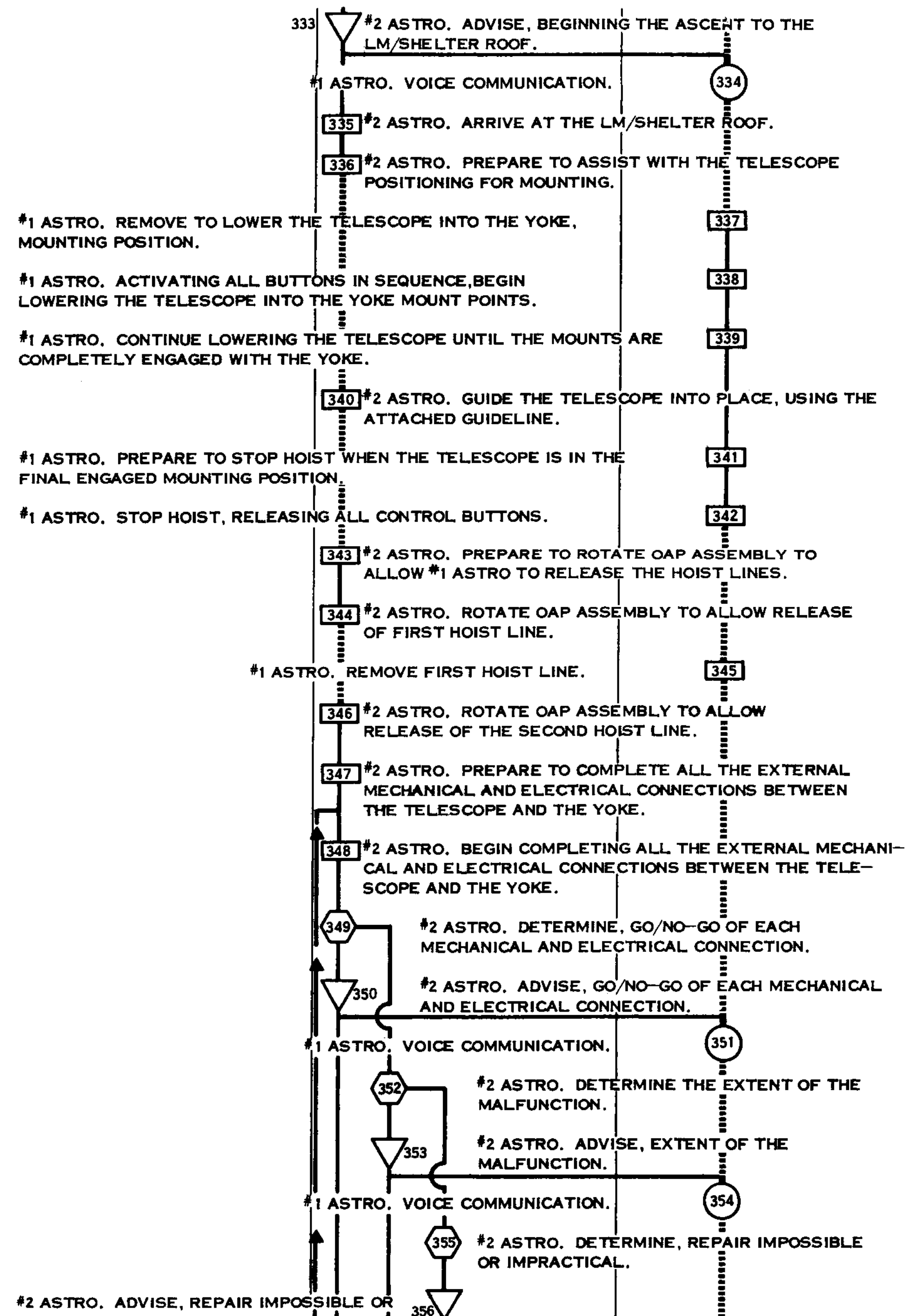
305 #1 ASTRO. PREPARE TO RAISE THE TELESCOPE USING THE "RAISE" CONTROL BUTTON.

306 #1 ASTRO. ACTIVATE "RAISE" CONTROL BUTTON.

307 #2 ASTRO. DETERMINE, GO/NO-GO OF THE HOIST



TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.


333
#2 ASTRO. ADVISE, BEGINNING THE ASCENT TO THE LM/SHELTER ROOF.
#1 ASTRO. VOICE COMMUNICATION.
334
335
#2 ASTRO. ARRIVE AT THE LM/SHELTER ROOF.
336
#2 ASTRO. PREPARE TO ASSIST WITH THE TELESCOPE POSITIONING FOR MOUNTING.
#1 ASTRO. REMOVE TO LOWER THE TELESCOPE INTO THE YOKE, MOUNTING POSITION.
337
#1 ASTRO. ACTIVATING ALL BUTTONS IN SEQUENCE,BEGIN LOWERING THE TELESCOPE INTO THE YOKE MOUNT POINTS.
338
#1 ASTRO. CONTINUE LOWERING THE TELESCOPE UNTIL THE MOUNTS ARE COMPLETELY ENGAGED WITH THE YOKE.
339
340
#2 ASTRO. GUIDE THE TELESCOPE INTO PLACE, USING THE ATTACHED GUIDELINE.
#1 ASTRO. PREPARE TO STOP HOIST WHEN THE TELESCOPE IS IN THE FINAL ENGAGED MOUNTING POSITION.
341
#1 ASTRO. STOP HOIST, RELEASING ALL CONTROL BUTTONS.
342
343
#2 ASTRO. PREPARE TO ROTATE OAP ASSEMBLY TO ALLOW #1 ASTRO TO RELEASE THE HOIST LINES.
344
#2 ASTRO. ROTATE OAP ASSEMBLY TO ALLOW RELEASE OF FIRST HOIST LINE.
#1 ASTRO. REMOVE FIRST HOIST LINE.
345
346
#2 ASTRO. ROTATE OAP ASSEMBLY TO ALLOW RELEASE OF THE SECOND HOIST LINE.
347
#2 ASTRO. PREPARE TO COMPLETE ALL THE EXTERNAL MECHANICAL AND ELECTRICAL CONNECTIONS BETWEEN THE TELESCOPE AND THE YOKE.
348
#2 ASTRO. BEGIN COMPLETING ALL THE EXTERNAL MECHANICAL AND ELECTRICAL CONNECTIONS BETWEEN THE TELESCOPE AND THE YOKE.
349
#2 ASTRO. DETERMINE, GO/NO-GO OF EACH MECHANICAL AND ELECTRICAL CONNECTION.
350
#2 ASTRO. ADVISE, GO/NO-GO OF EACH MECHANICAL AND ELECTRICAL CONNECTION.
#1 ASTRO. VOICE COMMUNICATION.
351
352
#2 ASTRO. DETERMINE THE EXTENT OF THE MALFUNCTION.
353
#2 ASTRO. ADVISE, EXTENT OF THE MALFUNCTION.
#1 ASTRO. VOICE COMMUNICATION.
354
355
#2 ASTRO. DETERMINE, REPAIR IMPOSSIBLE OR IMPRACTICAL.
#2 ASTRO. ADVISE, REPAIR IMPOSSIBLE OR
356

+325

IMPRACTICAL.

357 #1 ASTRO. VOICE COMMUNICATION.

358 #2 ASTRO. MISSION ABORT.

359 #2 ASTRO. BEGIN REPAIR OF THE MALFUNCTION.

360 #2 ASTRO. COMPLETE REPAIR OF THE MALFUNCTION.

+345

361 #2 ASTRO. CONTINUE WITH EXTERNAL MECHANICAL AND ELECTRICAL CONNECTIONS.

362 #1 ASTRO. PREPARE TO RETURN THE DERRICK TO THE RETRACTED, STORED POSITION.

363 #1 ASTRO. PREPARE TO SWING THE DERRICK OVER THE TOP OF THE LM/SHELTER ROOF TOWARDS THE STORAGE POSITION AREA, USING THE "RETRACT" CONTROL BUTTON.

364 #1 ASTRO. BEGIN THE SEQUENCE OF SWINGING THE DERRICK OVER THE LM/SHELTER ROOF.

365 #1 ASTRO. COMPLETE THE SEQUENCE OF SWINGING THE DERRICK OVER THE LM/SHELTER ROOF.

366 #1 ASTRO. CONTINUE TO RETRACT THE DERRICK UNTIL IT IS IN A POSITION APPROXIMATELY 45° ABOVE HORIZONTAL.

367 #1 ASTRO. PREPARE TO STOP THE DERRICK IN THE 45° ABOVE HORIZONTAL POSITION TO DISENGAGE THE MECHANICAL LOCKS.

368 #1 ASTRO. STOP RETRACT PROCEDURE.

369 #1 ASTRO. PREPARE TO STEP OFF THE WORK PLATFORM ONTO THE LM/SHELTER ROOF.

370 #1 ASTRO. STEP OFF THE WORK PLATFORM ONTO THE LM/SHELTER ROOF.

371 #1 ASTRO. MOVE AROUND OAP ASSEMBLY AND PREPARE TO RELEASE THE DERRICK LEG LOCKS, (3 LOCKS EACH LEG).

372 #1 ASTRO. RELEASE DERRICK LOCKS AND PREPARE TO CONTINUE WITH THE STORAGE SEQUENCE.

373 #1 ASTRO. ACTIVATE THE DERRICK "RETRACT" CONTROL BUTTON AND MONITOR THE STORAGE SEQUENCE.

374 #1 ASTRO. CONTINUE TO RETRACT THE DERRICK UNTIL IT REACHES THE STORED POSITION.

NOTE. LIMIT SWITCHES WILL STOP SEQUENCE WHEN MAXIMUM RETRACTED POSITION IS REACHED.

+375

375 #1 ASTRO. RETURN THE DERRICK CABLE CONTROL BOX TO ITS STORAGE POSITION.

376 #1 ASTRO. MOVE AROUND THE OAP ASSEMBLY AND PREPARE TO MOUNT THE WORK PLATFORM TO ACCOMPLISH THE GROSS ADJUSTMENT TASKS.

377 #1 ASTRO. MOUNT WORK PLATFORM

378 #1 ASTRO. PREPARE TO MAKE A GROSS POSITIONAL ADJUSTMENTS OF THE OAP.

379 #1 ASTRO. MAKE GROSS POSITIONAL ADJUSTMENT.

TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.

380 #1 ASTRO. ADVISE, GROSS POSITIONING ADJUSTMENT COMPLETED.

381 #2 ASTRO. VOICE COMMUNICATION.

382 #1 ASTRO. PREPARE TO INSTALL FILTER ASSEMBLY.

383 #1 ASTRO. OPEN ACCESS PANEL AND INSTALL FILTER ASSEMBLY.

384 #1 ASTRO. PREPARE TO INSTALL FILM PACK.

385 #1 ASTRO. OPEN ACCESS PANEL AND INSTALL FILM PACK.

386 #1 ASTRO. PREPARE TO DISMOUNT FROM THE WORK PLATFORM.

387 #1 ASTRO. DISMOUNT FROM THE WORK PLATFORM AND PREPARE TO STORE THE WORK PLATFORM EXTENSION.

+390

388 #1 ASTRO. RETRACT THE WORK PLATFORM EXTENSION TO ALLOW CLEAR-ANCE IN THE AREA OF THE TELESCOPE.

389 #1 ASTRO. PREPARE TO DESCEND THE EXTERNAL LM/SHELTER LADDER AND INGRESS THE LM/SHELTER.

390 #1 ASTRO. BEGIN THE DESCENT OF THE EXTERNAL LM/SHELTER EXTERNAL LADDER.

391 #1 ASTRO. ADVISE, BEGINNING DESCENT TO THE EXTERNAL SIDE HATCH.

392 #2 ASTRO. VOICE COMMUNICATION.

+395

393 #1 ASTRO. ARRIVE AT THE LM/SHELTER EXTERNAL SIDE HATCH AND PREPARE TO INGRESS.

394 #1 ASTRO. BEGIN THE INGRESS THROUGH THE LM/SHELTER EXTERNAL SIDE HATCH.

395 #1 ASTRO. COMPLETE INGRESS THROUGH THE LM/SHELTER EXTERNAL SIDE HATCH.

396 #1 ASTRO. ADVISE, INGRESS INTO THE LM/SHELTER COMPLETE.

+400

397 #2 ASTRO. VOICE COMMUNICATION.

398 #1 ASTRO. PREPARE TO COMPLETE THE INTERNAL LM/SHELTER – YOKE INTERFACE SEAL.

399 #1 ASTRO. BEGIN TO COMPLETE THE INTERNAL LM/SHELTER – YOKE INTERFACE SEAL.

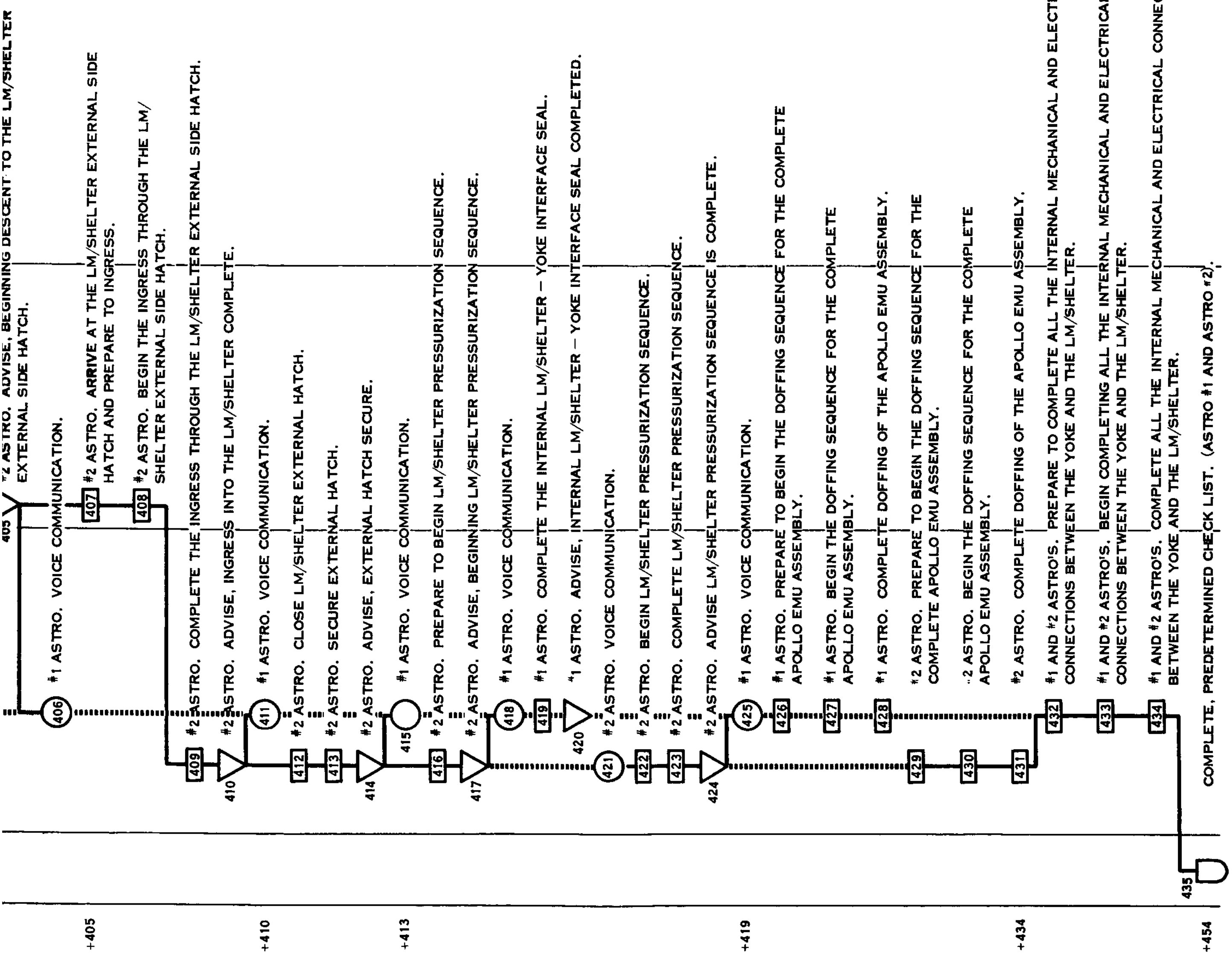
400 #2 ASTRO. COMPLETE ALL EXTERNAL MECHANICAL AND ELECTRICAL CONNECTIONS.

401 #2 ASTRO. ADVISE, ALL EXTERNAL CONNECTIONS COMPLETE.

402 #1 ASTRO. VOICE COMMUNICATION.

403 #2 ASTRO. PREPARE TO DESCEND THE EXTERNAL LM/SHELTER LADDER AND INGRESS THE LM/SHELTER.

404 #2 ASTRO. BEGIN THE DESCENT OF THE EXTERNAL LM/SHELTER EXTERNAL LADDER.



TIME LINE ANALYSIS FOR LUNAR SURFACE EXPERIMENTS, OAP ERECTION AND DEPLOYMENT.

APPENDIX B

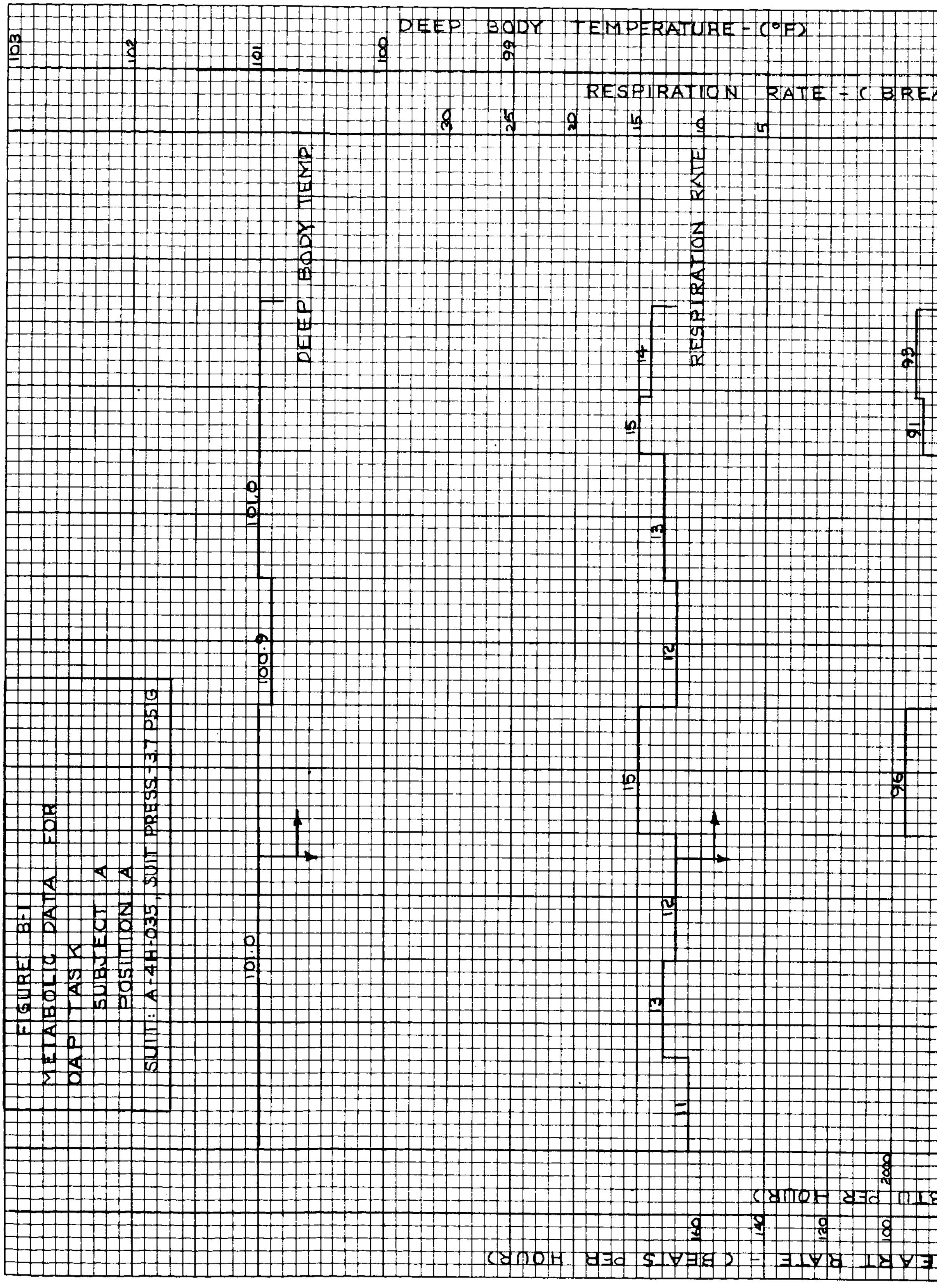
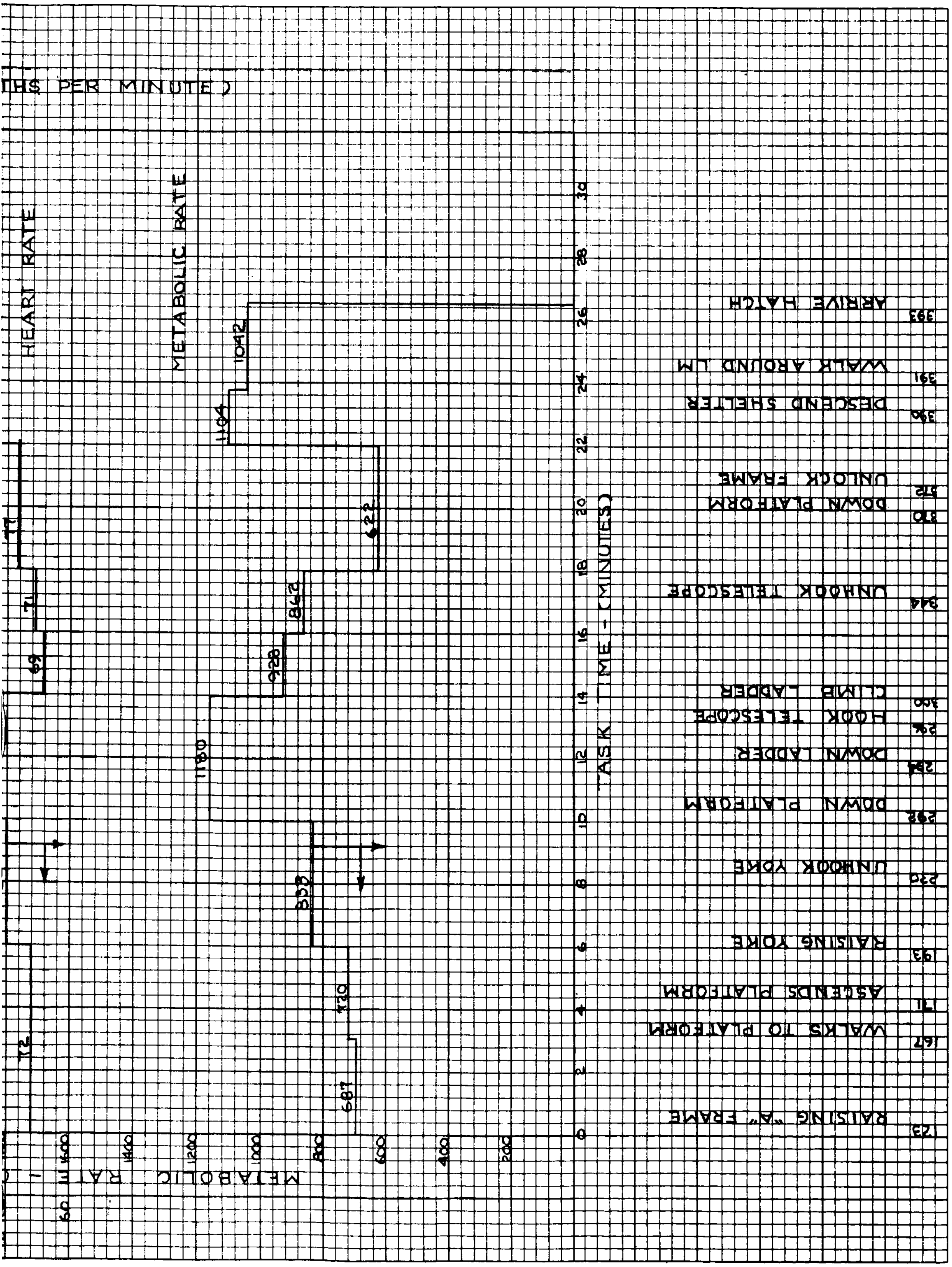


FIGURE B-1
METABOLIC DATA FOR
OAP TASK K
SUBJECT A
POSITION A
SUIT: A-4H-035, SUIT PRESS-3.7 PSIG
DEEP BODY TEMPERATURE - (°F)
RESPIRATION RATE - (BREA
DEEP BODY TEMP
RESPIRATION RATE
HEART RATE - (BEATS PER HOUR)
BTU PER HOUR



(THS PER MINUTE)
HEART RATE
METABOLIC RATE
TASK TIME - (MINUTES)
METABOLIC RATE
ARRIVE HATCH
WALK AROUND LM
DESCEND SHELTER
UNLOCK FRAME
DOWN PLATFORM
UNHOOK TELESCOPE
CLIMB LADDER
HOOK TELESCOPE
DOWN LADDER
DOWN PLATFORM
UNHOOK YOKE
RAISING YOKE
ASCENDS PLATFORM
WALKS TO PLATFORM
RAISING "A" FRAME

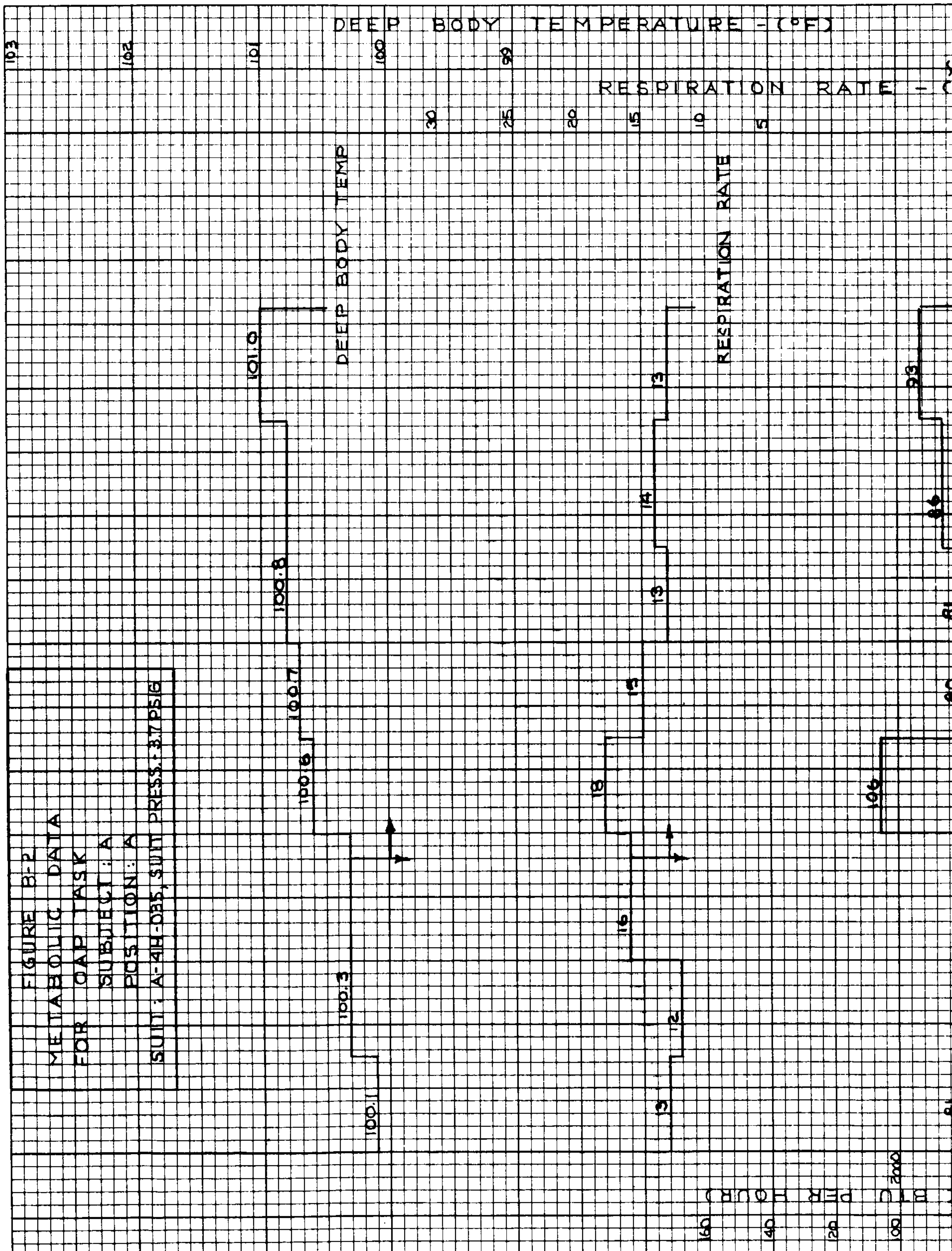
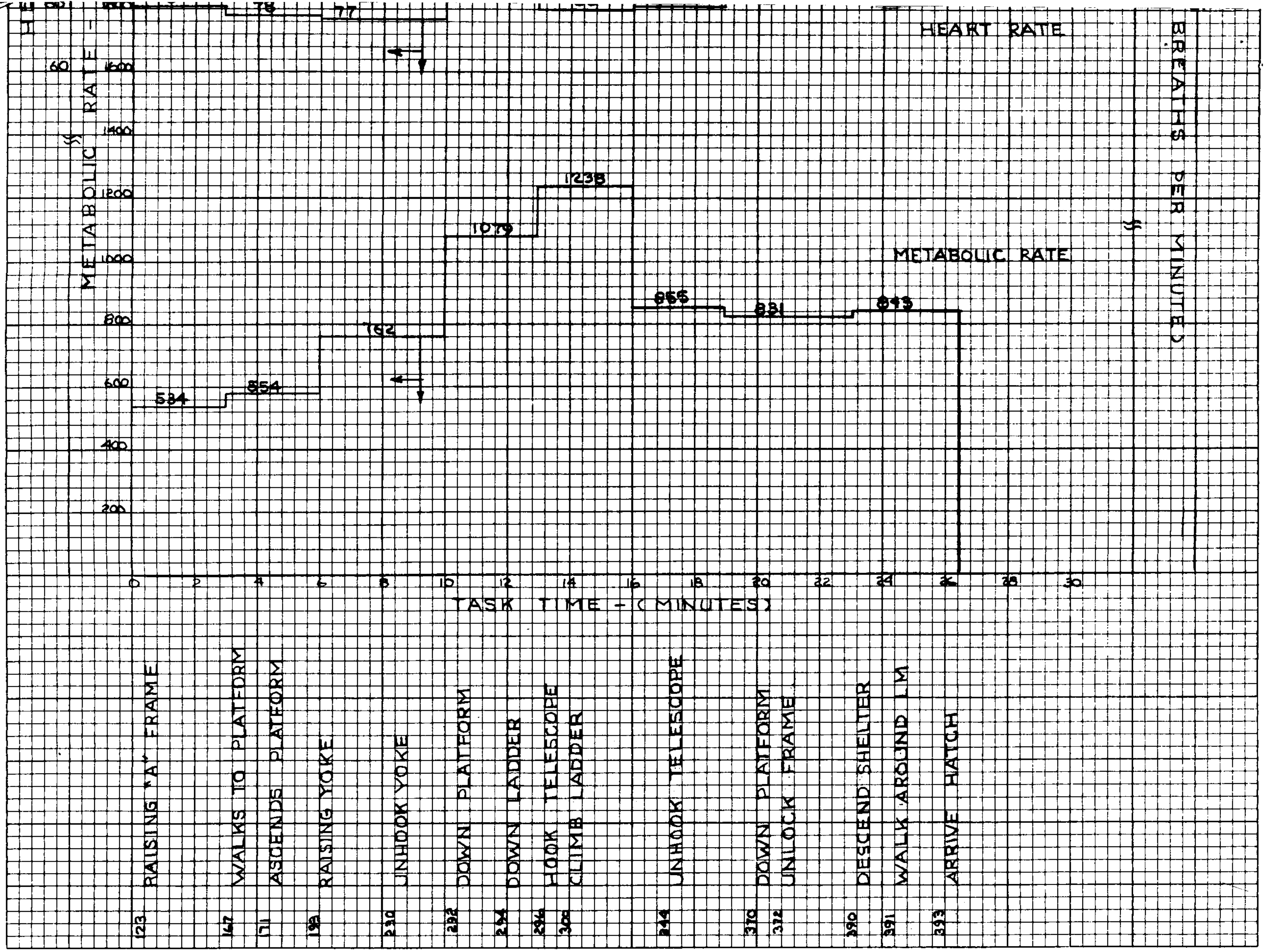


FIGURE B-2
METABOLIC DATA
FOR OAP TASK
SUBJECT: A
POSITION: A
SUIT: A-4H-035, SUIT PRESS: 3.7 PSIG


HEART RATE
METABOLIC RATE
BREATHS PER MINUTE)
METABOLIC RATE
60
1600
1400
1200
1000
800
600
400
200
534
554
762
1079
1238
865
831
843
78
77
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TASK TIME - (MINUTES)
123 RAISING "A" FRAME
147 WALKS TO PLATFORM
171 ASCENDS PLATFORM
193 RAISING YOKE
230 UNHOOK YOKE
252 DOWN PLATFORM
264 DOWN LADDER
296 HOOK TELESCOPE
300 CLIMB LADDER
344 UNHOOK TELESCOPE
370 DOWN PLATFORM
372 UNLOCK FRAME
390 DESCEND SHELTER
391 WALK AROUND LM
393 ARRIVE HATCH

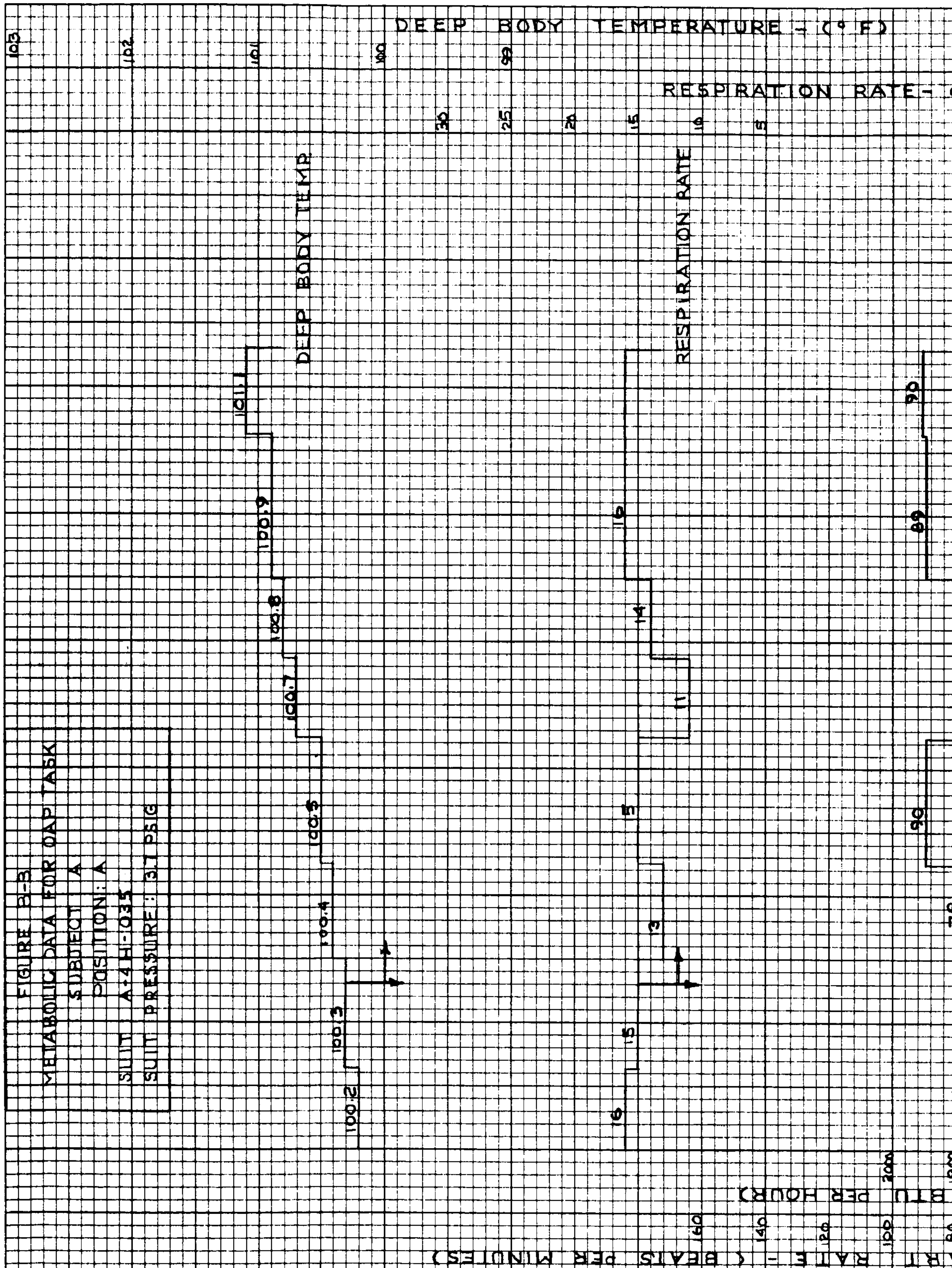
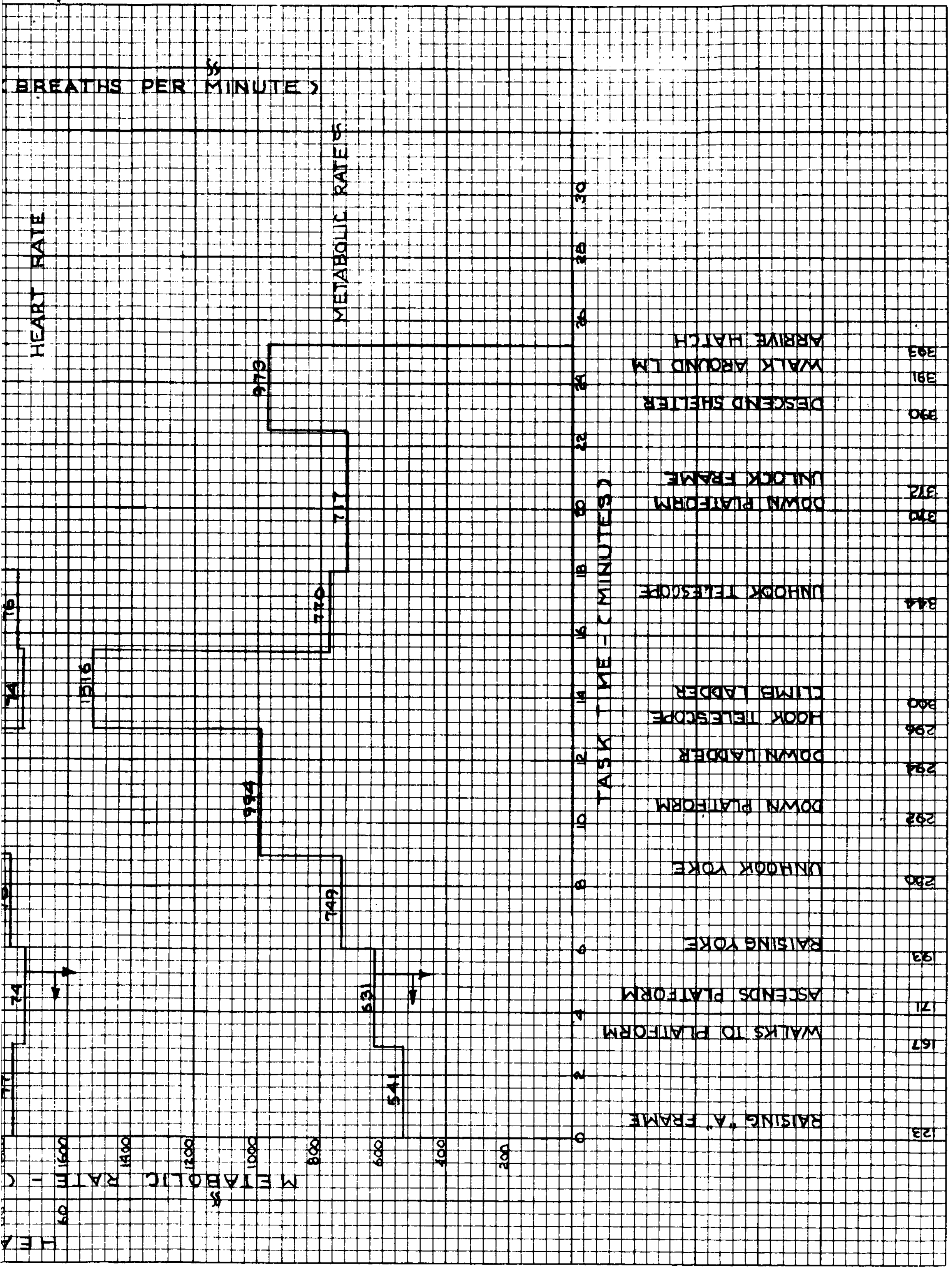


FIGURE B-3
METABOLIC DATA FOR OAP TASK
SUBJECT: A
POSITION: A
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG


(BREATHS PER MINUTE)
HEART RATE
METABOLIC RATE
TASK TIME (MINUTES)
METABOLIC RATE
RAISING "A" FRAME
WALKS TO PLATFORM
ASCENDS PLATFORM
RAISING YOKE
UNHOOK YOKE
DOWN PLATFORM
DOWN LADDER
HOOK TELESCOPE
CLIMB LADDER
UNHOOK TELESCOPE
DOWN PLATFORM
UNLOCK FRAME
DESCEND SHELTER
WALK AROUND LM
ARRIVE HATCH
541
531
749
994
1316
770
717
973

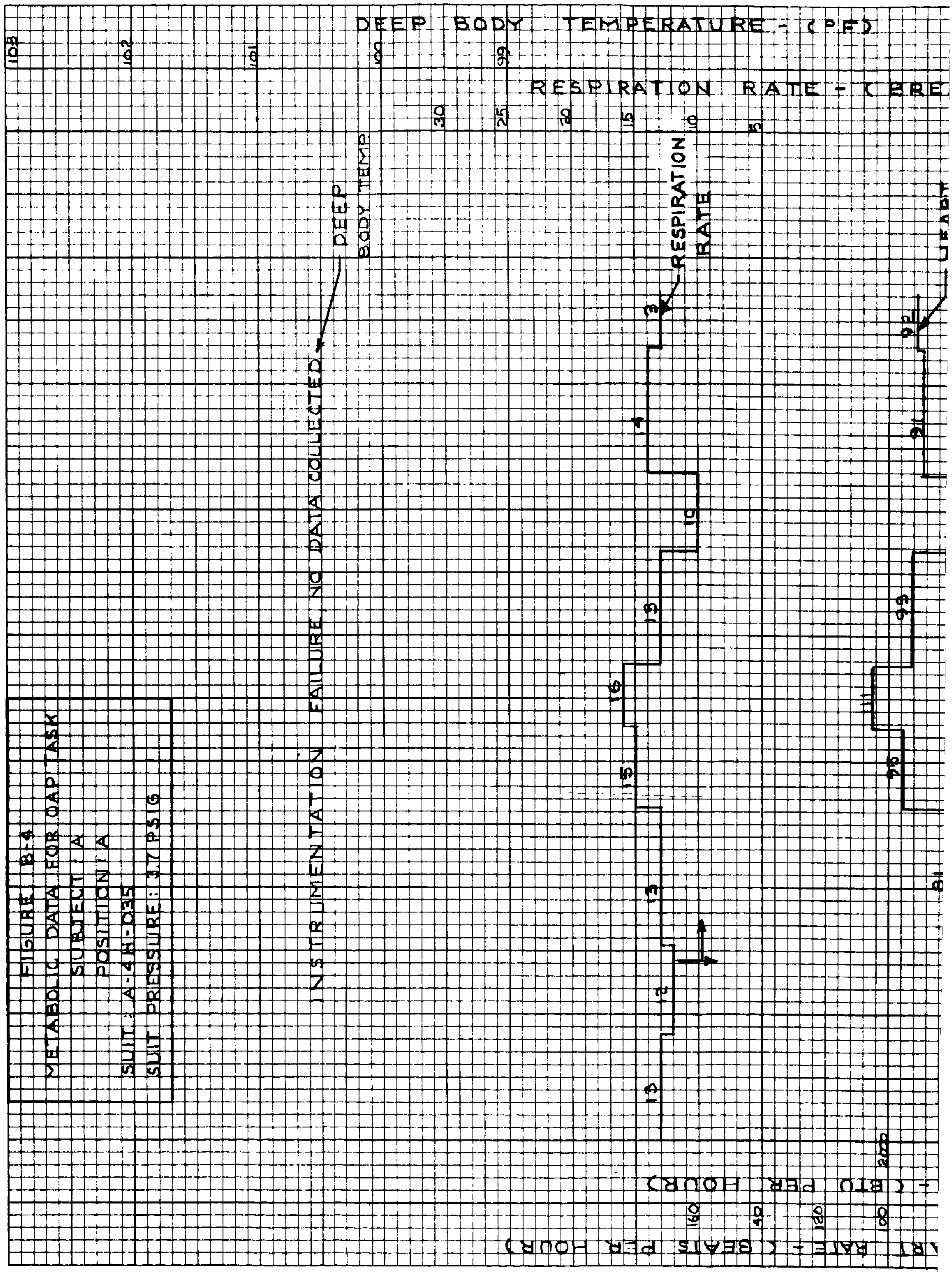
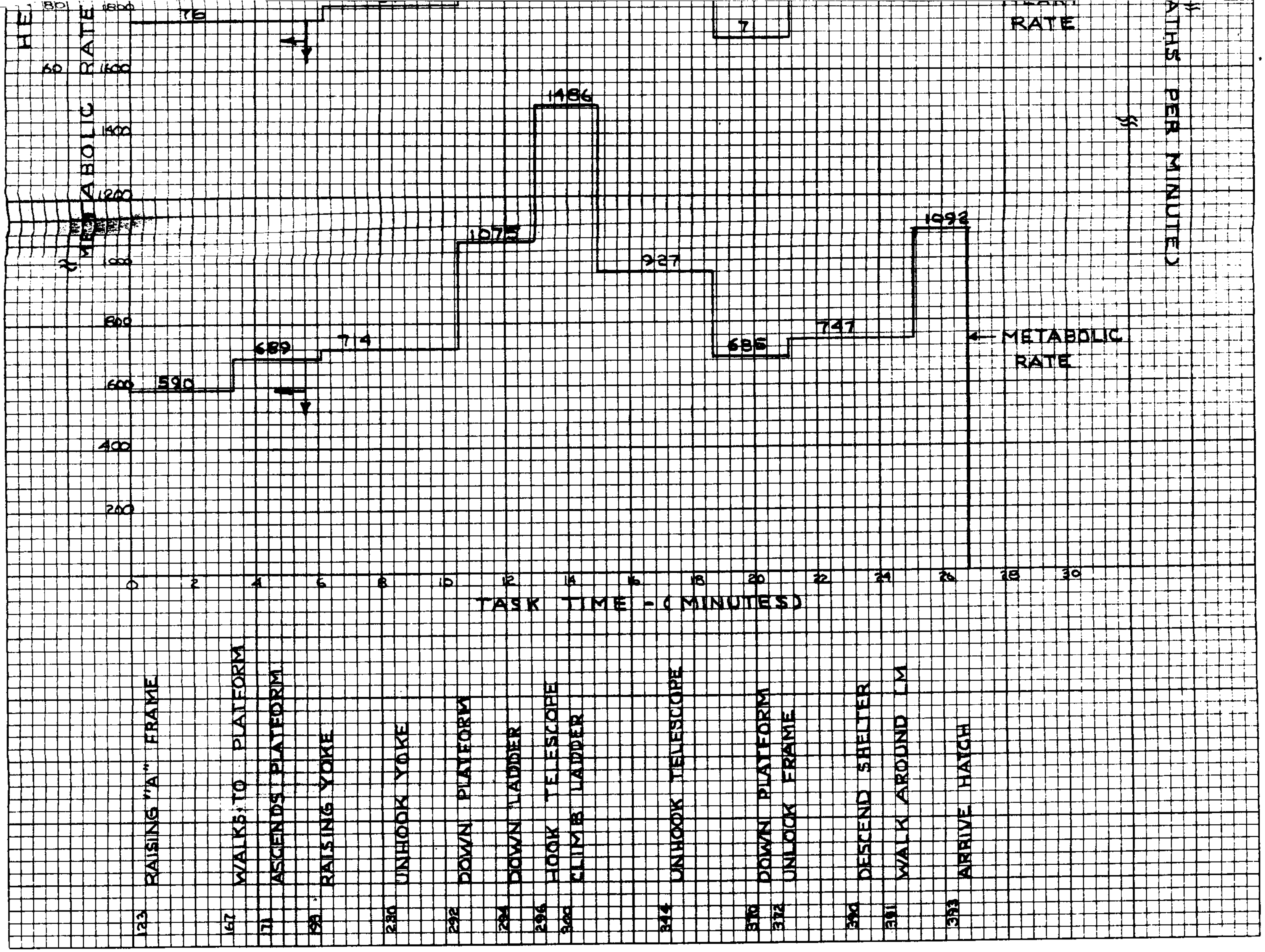


FIGURE B-4
METABOLIC DATA FOR OAP TASK
SUBJECT: A
POSITION: A
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG



METABOLIC RATE
ATHS PER MINUTE)
RATE
METABOLIC RATE
TASK TIME - (MINUTES)
590
689
714
1075
1486
927
686
747
1092
76
7
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
200
400
600
800
1000
1200
1400
1600
1800
60
80
RAISING "A" FRAME
WALKS TO PLATFORM
ASCENDS PLATFORM
RAISING YOKE
UNHOOK YOKE
DOWN PLATFORM
DOWN LADDER
HOOK TELESCOPE
CLIMB LADDER
UNHOOK TELESCOPE
DOWN PLATFORM
UNLOCK FRAME
DESCEND SHELTER
WALK AROUND LM
ARRIVE HATCH
123
167
171
193
230
292
294
296
300
344
370
372
390
391
393

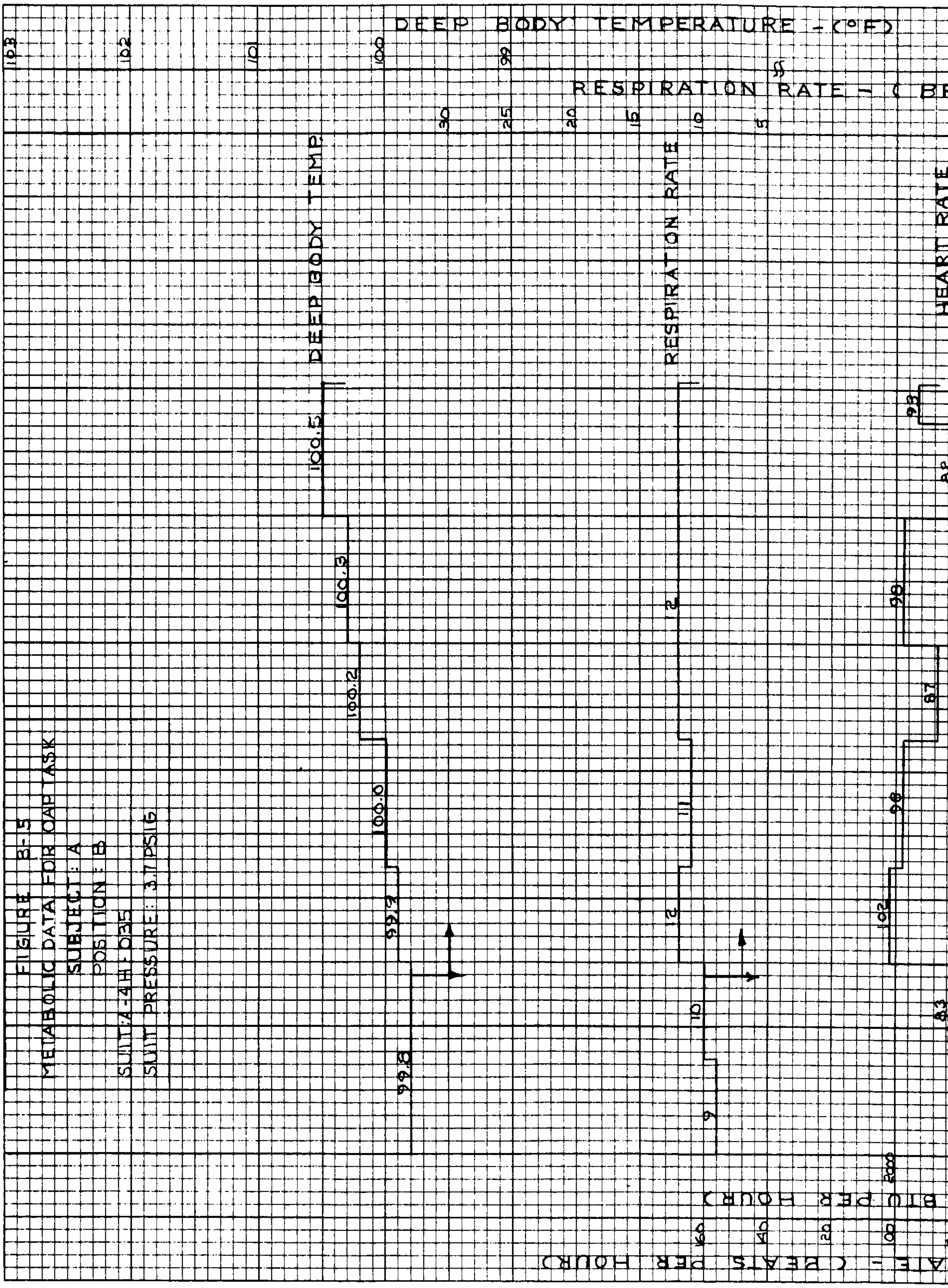
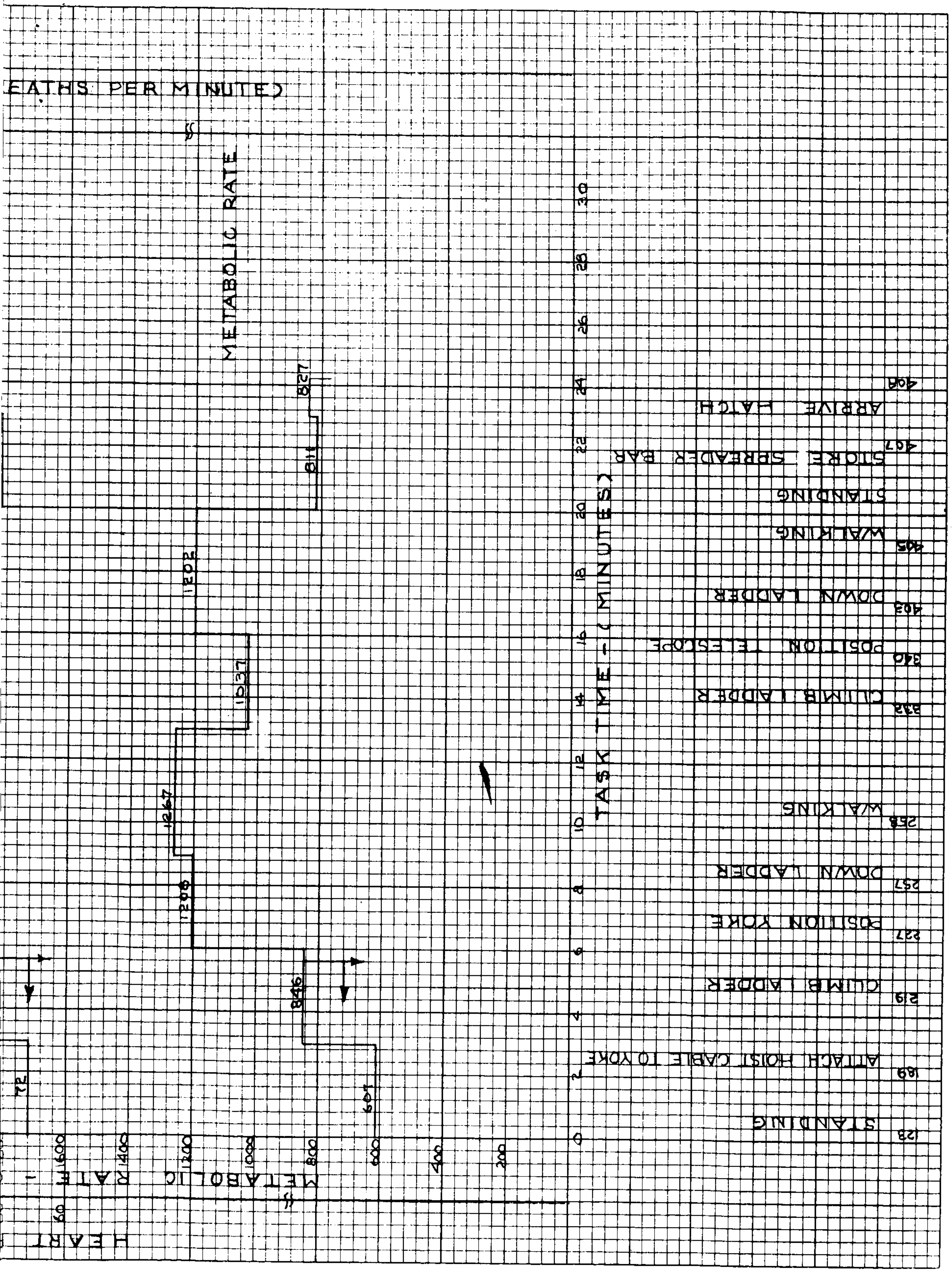


FIGURE B-5
METABOLIC DATA FOR OAP TASK
SUBJECT: A
POSITION: B
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG



EATHS PER MINUTE)
METABOLIC RATE
TASK TIME - (MINUTES)
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH

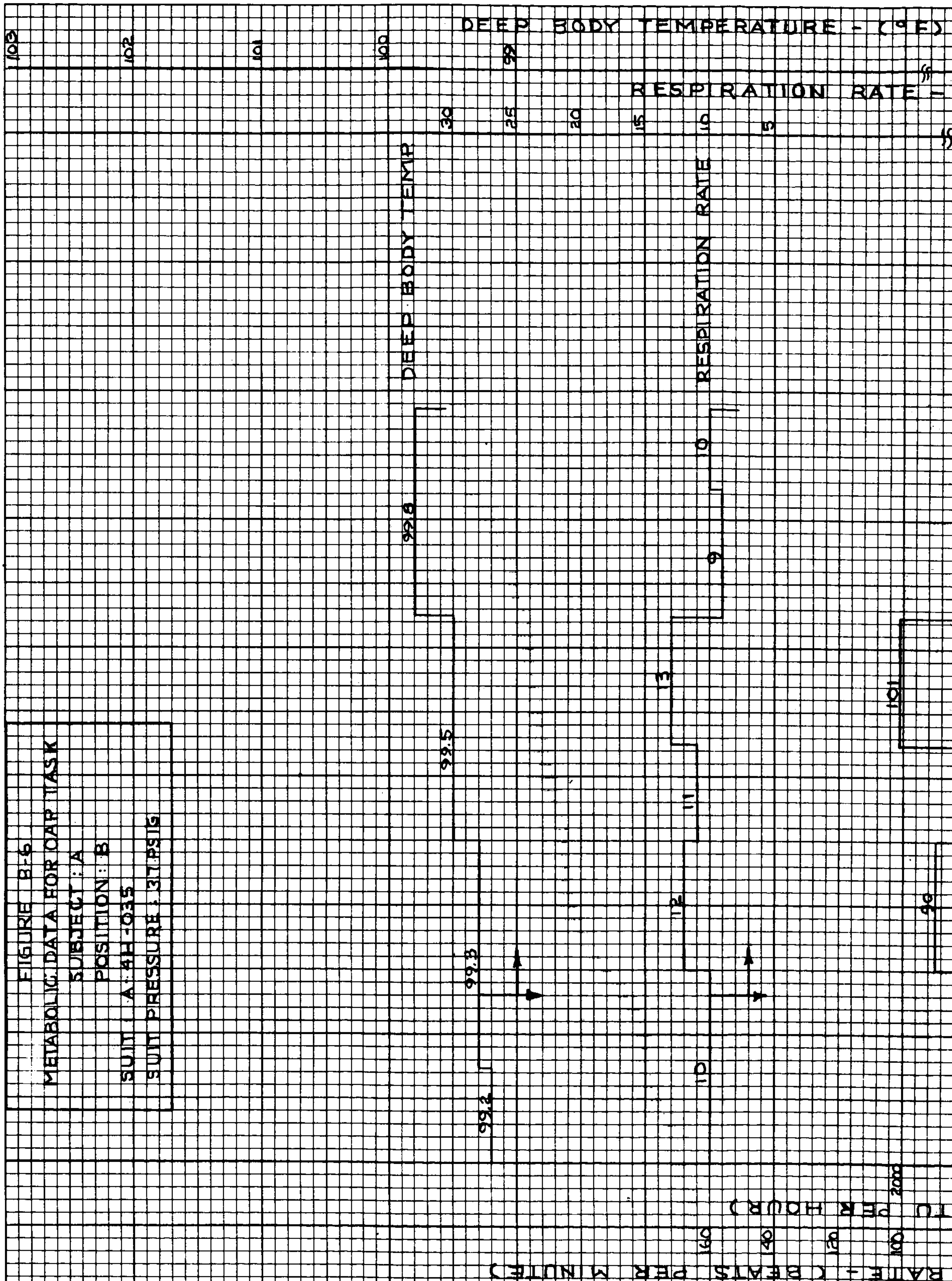
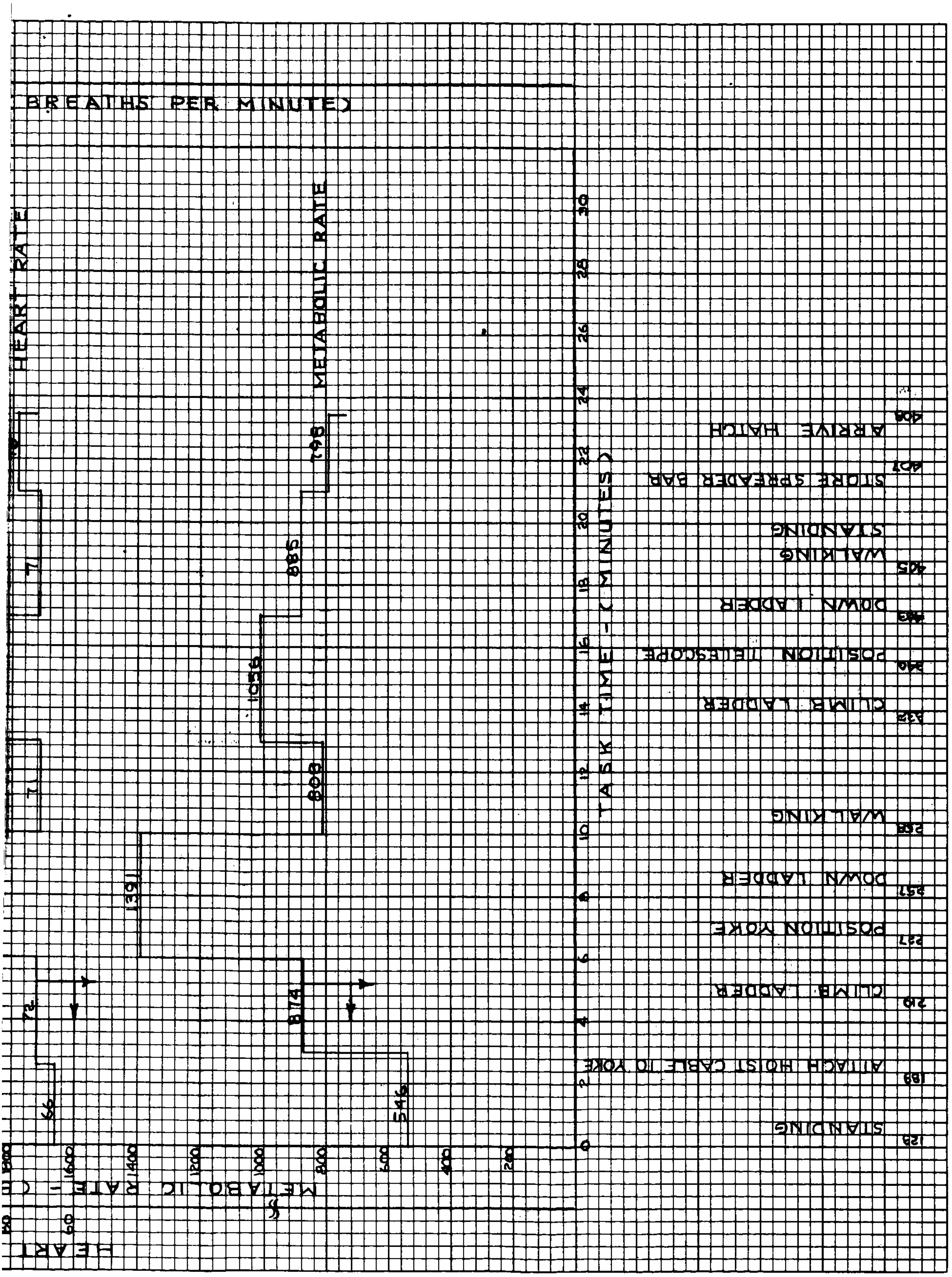


FIGURE B-6
METABOLIC DATA FOR OAP TASK
SUBJECT : A
POSITION : B
SUIT : A 4H-035
SUIT PRESSURE : 3.7 PSIG


BREATHS PER MINUTE
HEART RATE
METABOLIC RATE
TASK TIME - (MINUTES)
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH
546
874
1391
808
1036
885
798
66
72
HEART

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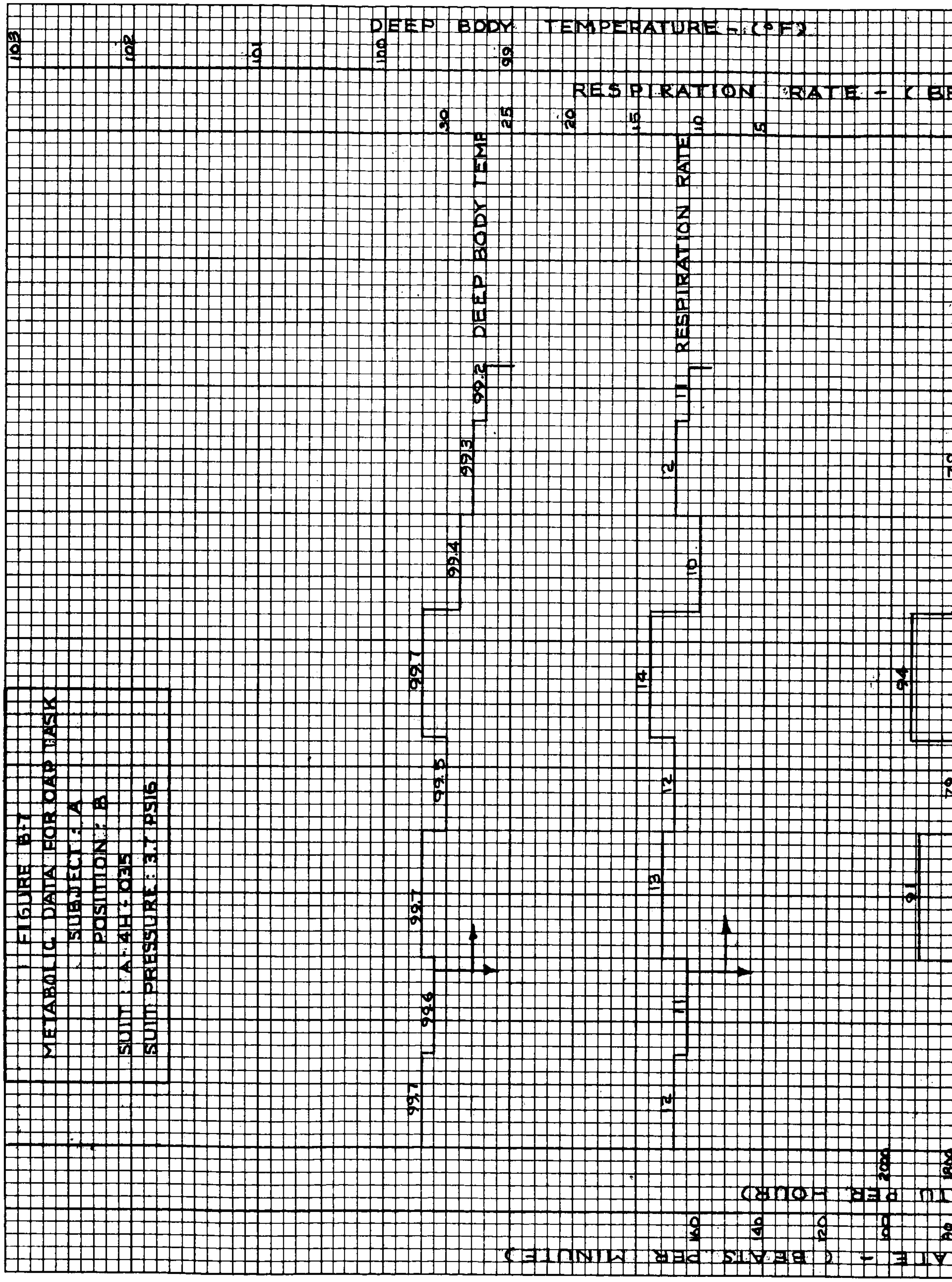
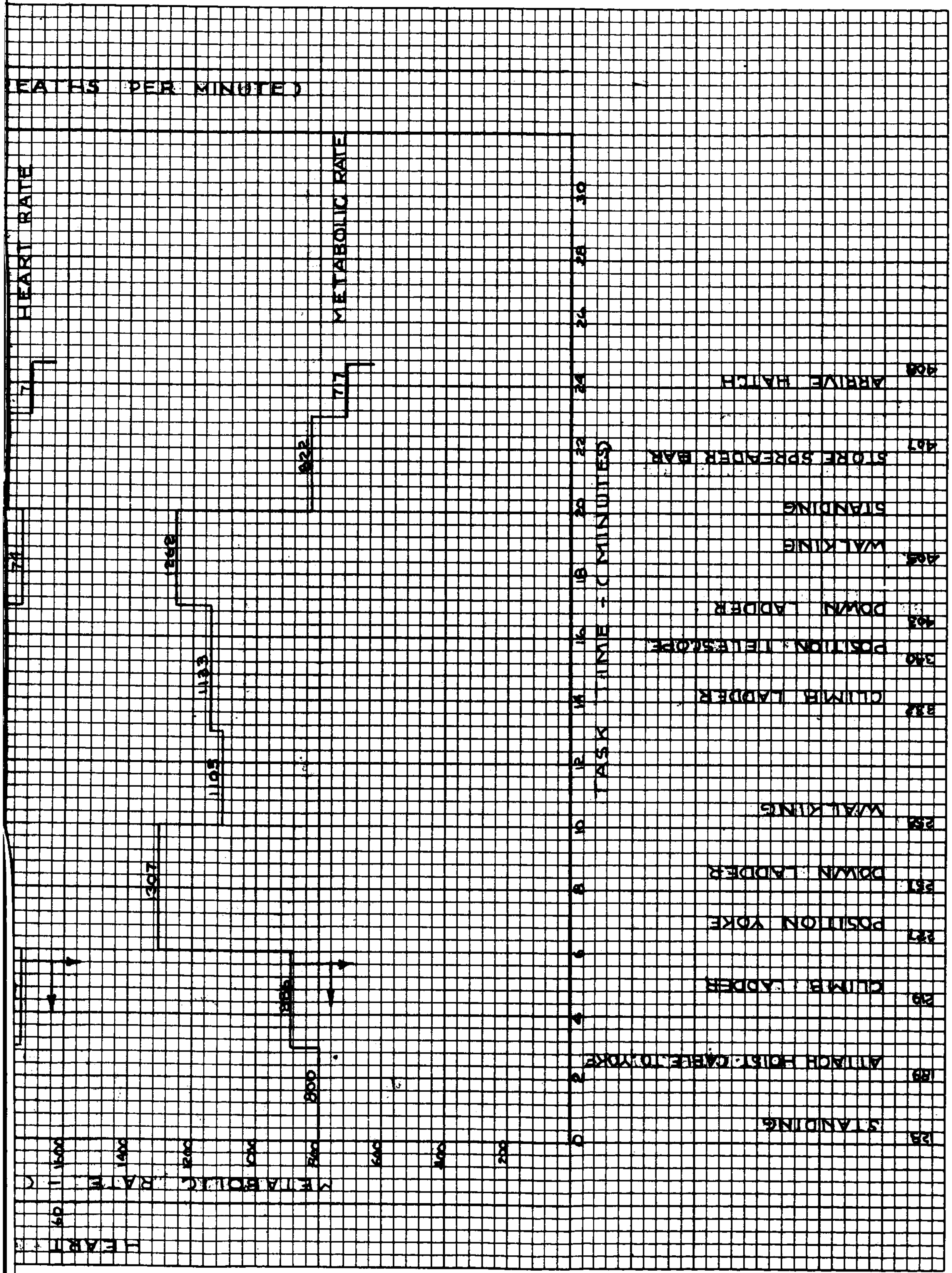
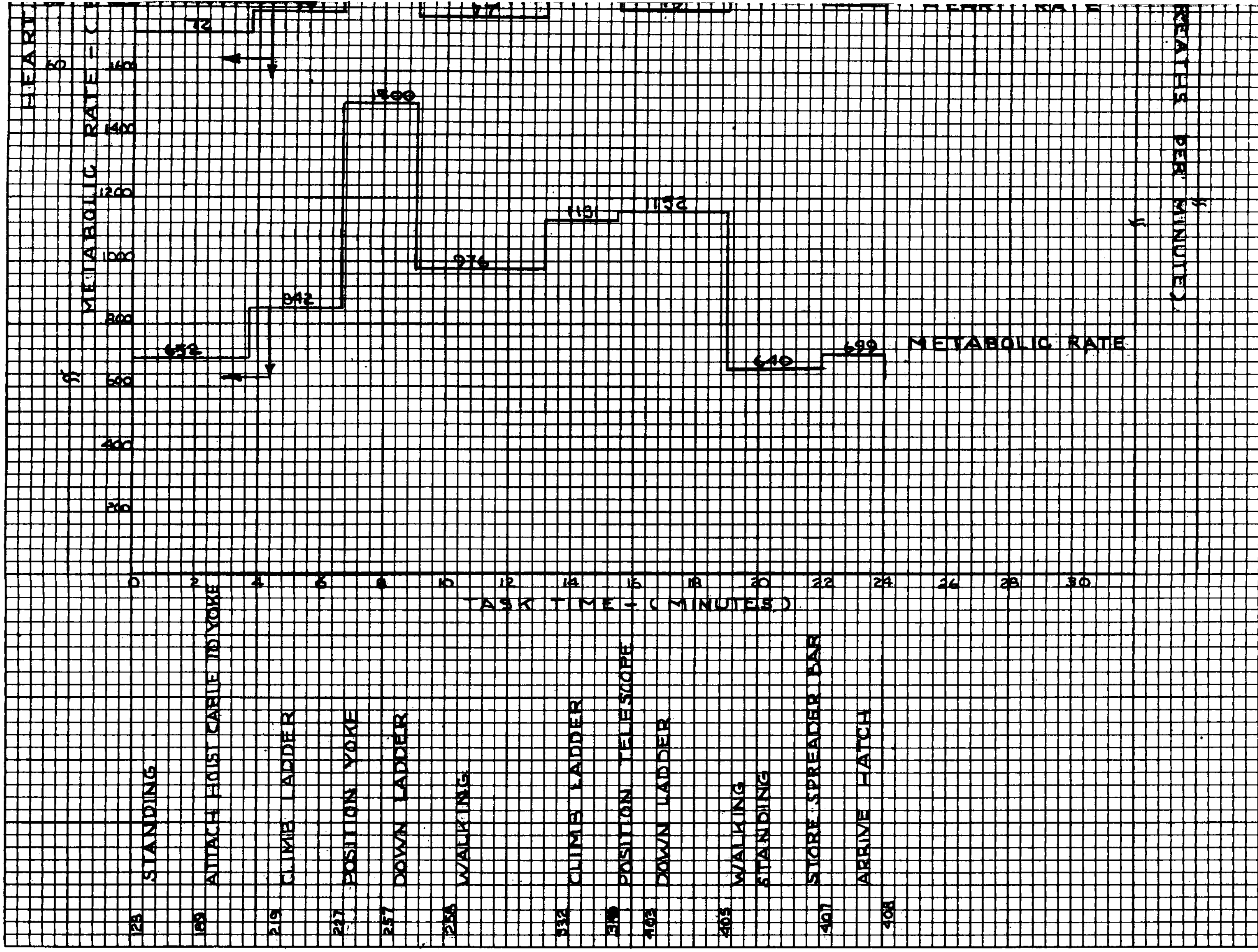


FIGURE B-7
METABOLIC DATA FOR OAP TASK
SUBJECT : A
POSITION : B
SUIT : A-4H-035
SUIT PRESSURE : 3.7 PSIG



EATHS PER MINUTE)
HEART RATE
METABOLIC RATE
TASK TIME - (MINUTES)
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH
HEART
METABOLIC RATE


FIGURE B-8
METABOLIC DATA FOR OAP TASK
SUBJECT: A
POSITION:
SUIT: A-4-H-035
SUIT PRESSURE: 3.7 PSIG
INSTRUMENTATION FAILURE, NO DATA COLLECTED
DEEP BODY TEMP
RESPIRATION RATE
RESPIRATION RATE - (B
103
102
101
100
99
30
25
20
15
10
5
16
15
14
15
19
15
13
12
110
69
65
RATE - (BEATS PER MINUTE)
160
140
120
100
TU PER HOUR)
2000


HEART
60
METABOLIC RATE - (
1600
1400
1200
1000
800
600
400
200
REATHS PER MINUTE)
METABOLIC RATE
652
842
1500
976
1131
1152
640
699
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TASK TIME - (MINUTES)
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH
128
189
219
227
257
258
332
403
405
407
408

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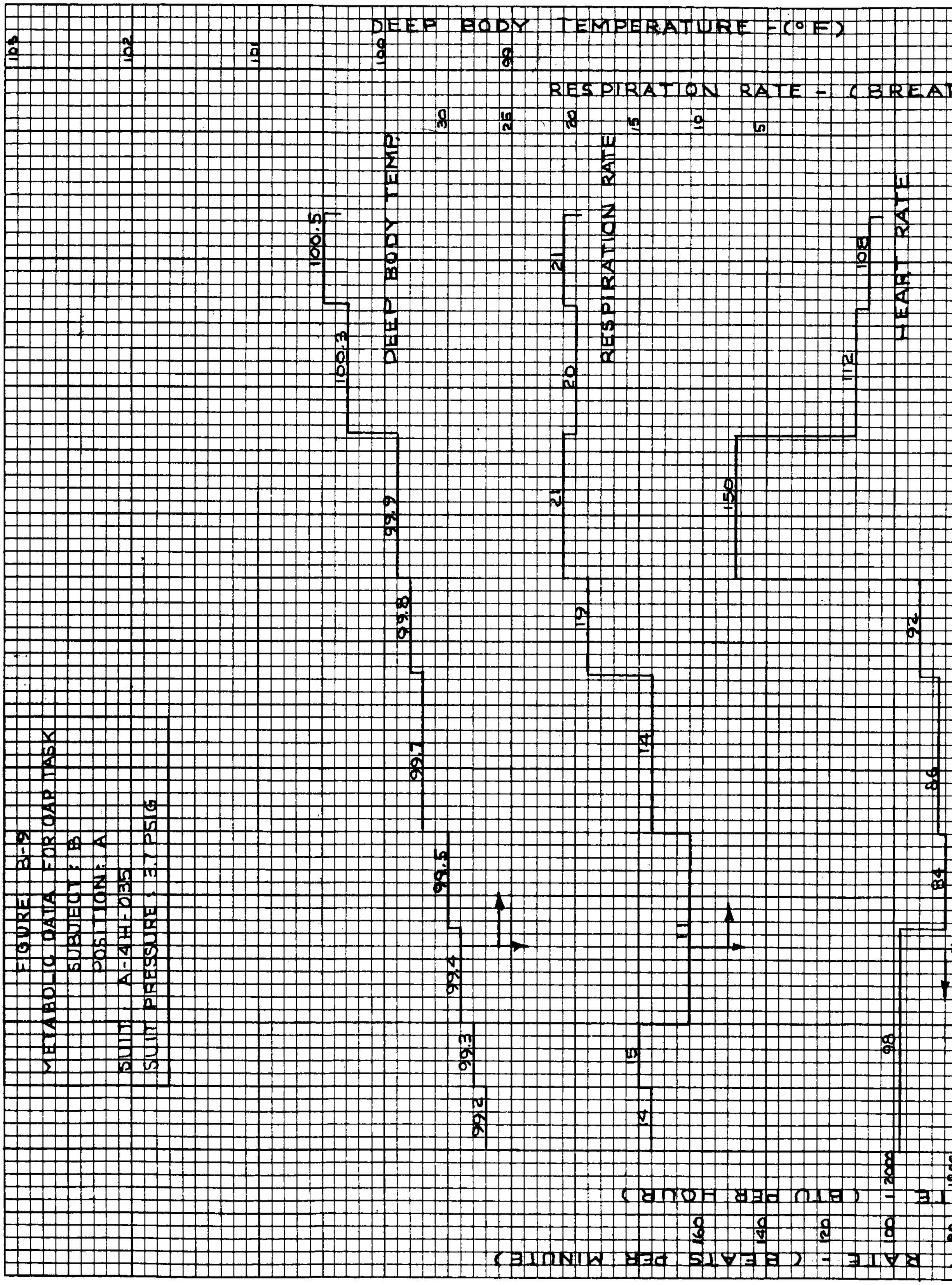

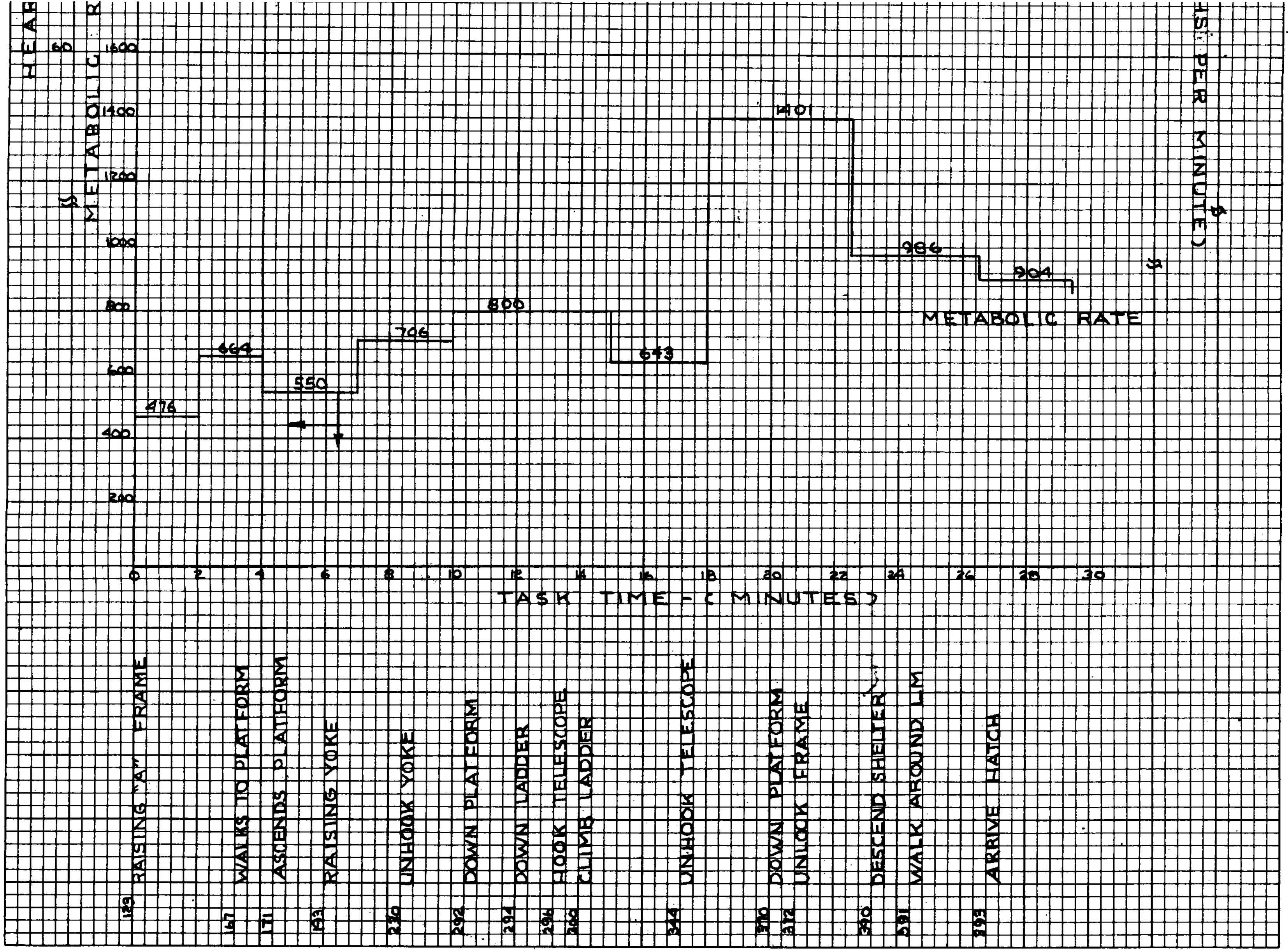
HEAR
METABOLIC R
(... HS PER MINUTE)
METABOLIC RATE
60
1600
1400
1200
1000
800
600
400
200
476
664
550
706
800
643
1401
966
904
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TASK TIME - (MINUTES)
123 RAISING "A" FRAME
167 WALKS TO PLATFORM
171 ASCENDS PLATFORM
193 RAISING YOKE
230 UNHOOK YOKE
292 DOWN PLATFORM
294 DOWN LADDER
296 HOOK TELESCOPE
300 CLIMB LADDER
344 UNHOOK TELESCOPE
310 DOWN PLATFORM
312 UNLOCK FRAME
390 DESCEND SHELTER
391 WALK AROUND LM
393 ARRIVE HATCH

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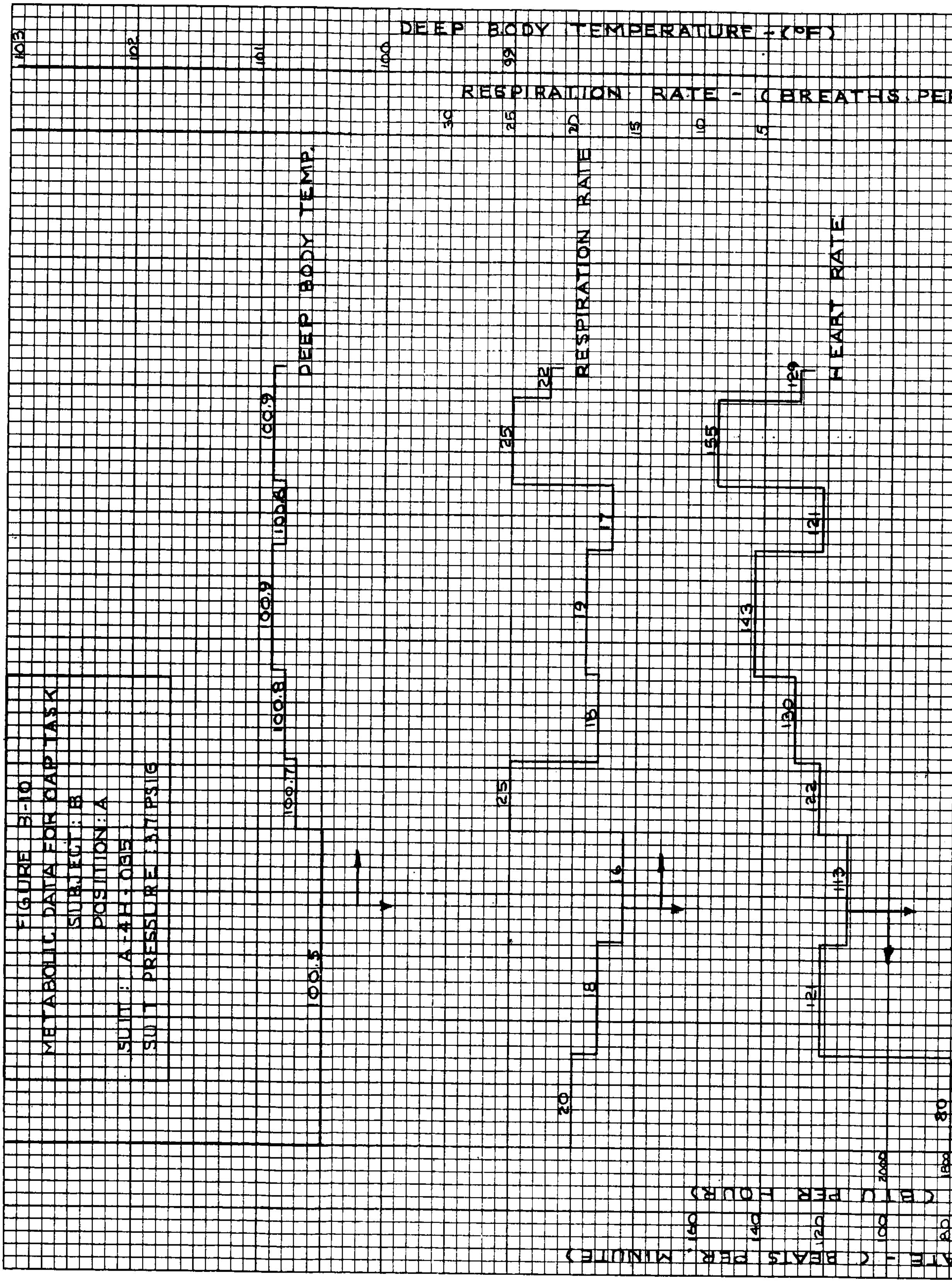
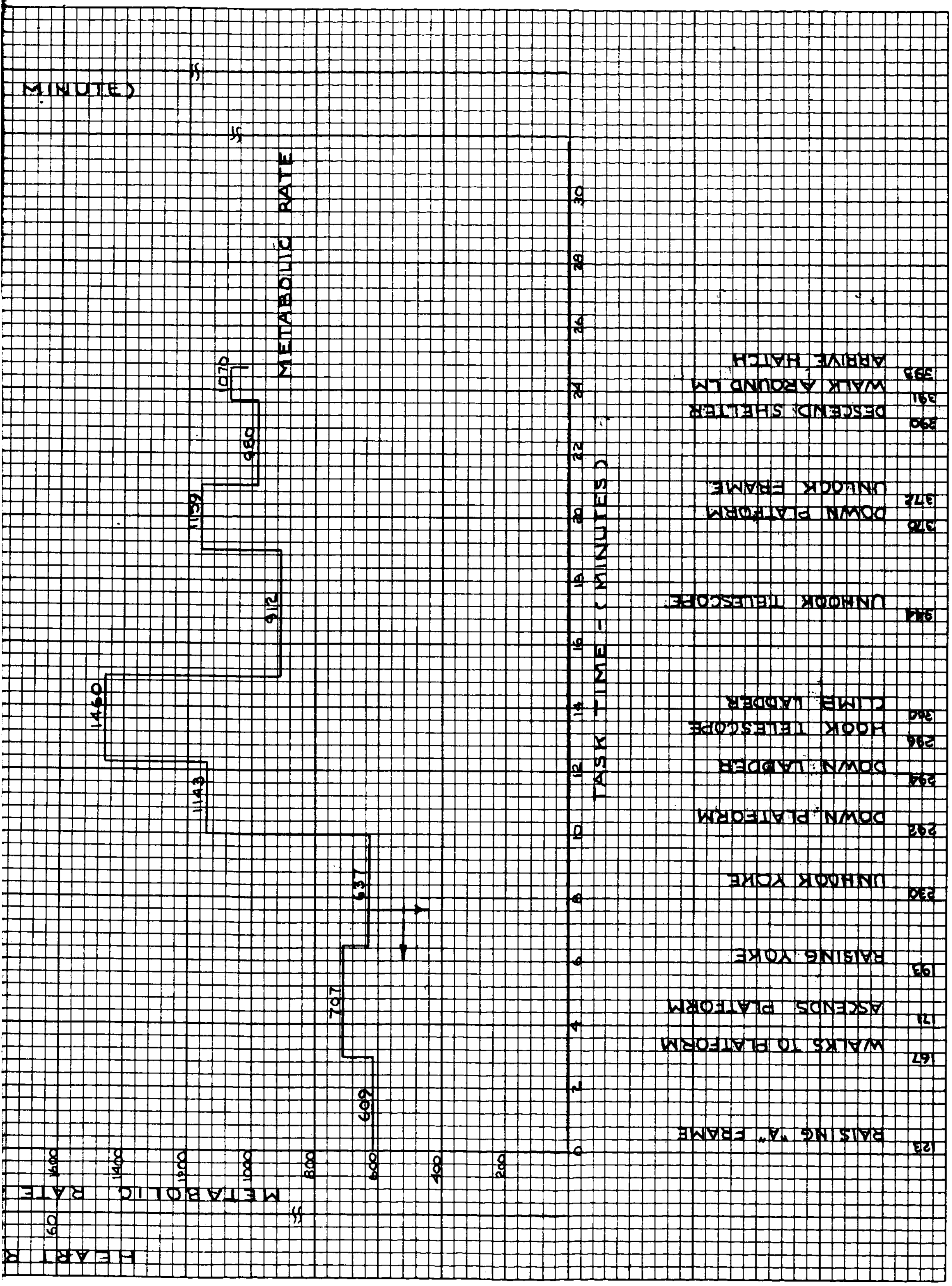



METABOLIC RATE
TASK TIME - (MINUTES)
MINUTES)
METABOLIC RATE
HEART R
609
707
637
1143
1460
912
1139
950
1070
RAISING "A" FRAME
WALKS TO PLATFORM
ASCENDS PLATFORM
RAISING YOKE
UNHOOK YOKE
DOWN PLATFORM
DOWN LADDER
HOOK TELESCOPE
CLIMB LADDER
UNHOOK TELESCOPE
DOWN PLATFORM
UNLOCK FRAME
DESCEND SHELTER
WALK AROUND LM
ARRIVE HATCH

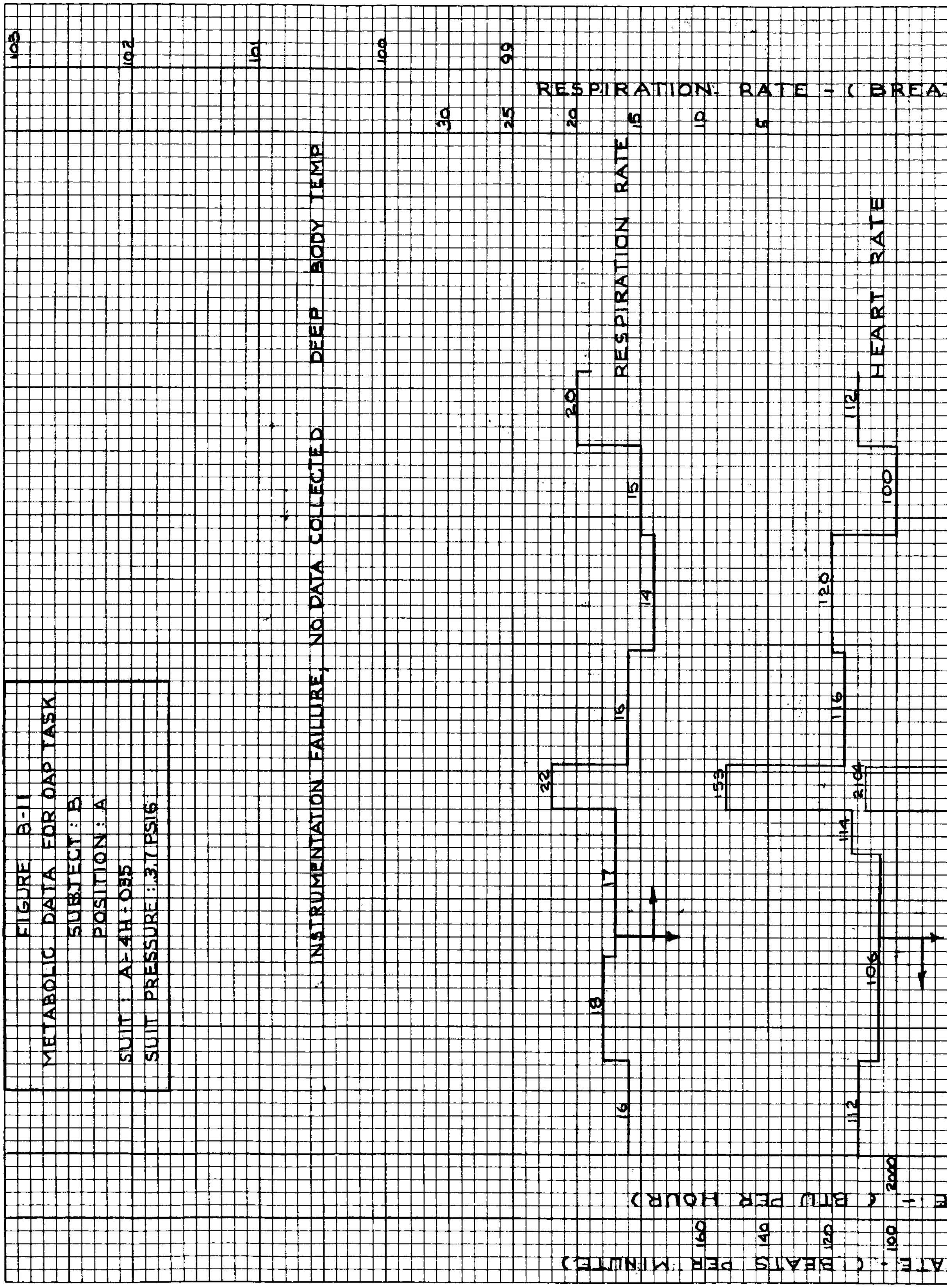
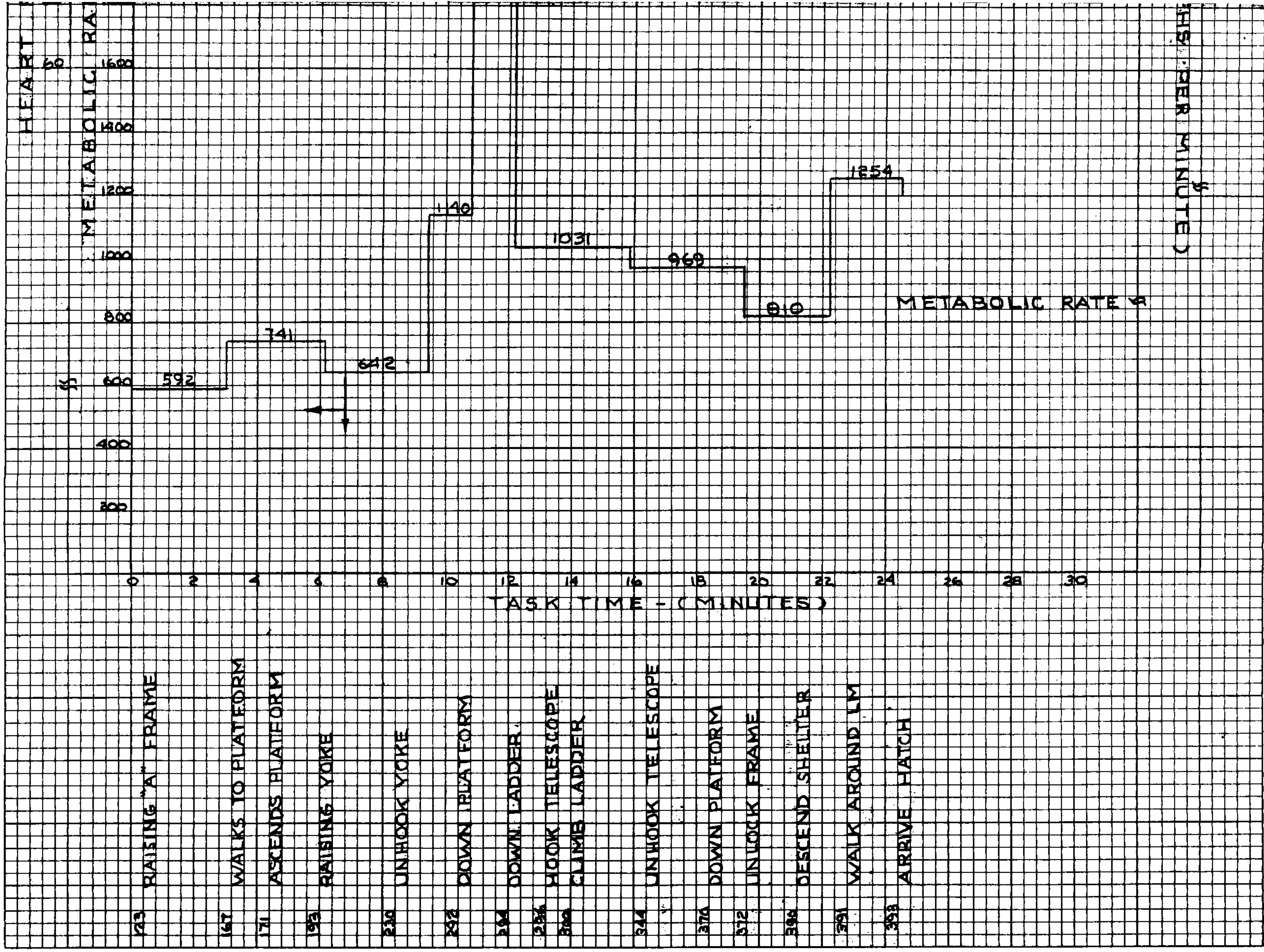


FIGURE B-11
METABOLIC DATA FOR OAP TASK
SUBJECT: B
POSITION: A
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG


HEART
60
METABOLIC RA
1600
1400
1200
1000
800
600
400
200
592
741
642
1140
1031
969
810
1254
METABOLIC RATE
HS PER MINUTE)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TASK TIME - (MINUTES)
123 RAISING "A" FRAME
167 WALKS TO PLATFORM
171 ASCENDS PLATFORM
193 RAISING YOKE
230 UNHOOK YOKE
292 DOWN PLATFORM
294 DOWN LADDER
296 HOOK TELESCOPE
300 CLIMB LADDER
344 UNHOOK TELESCOPE
370 DOWN PLATFORM
372 UNLOCK FRAME
396 DESCEND SHELTER
391 WALK AROUND LM
393 ARRIVE HATCH

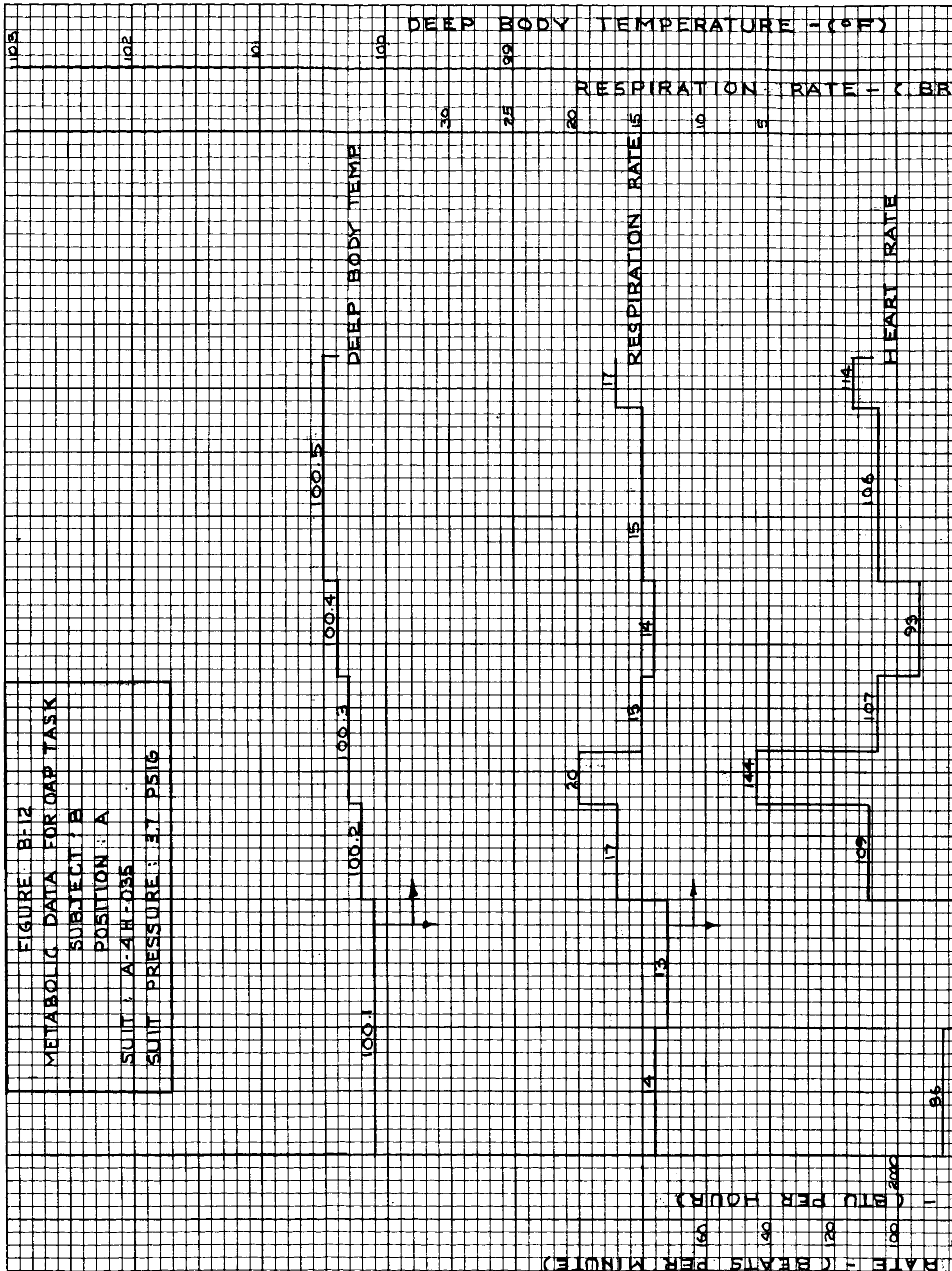
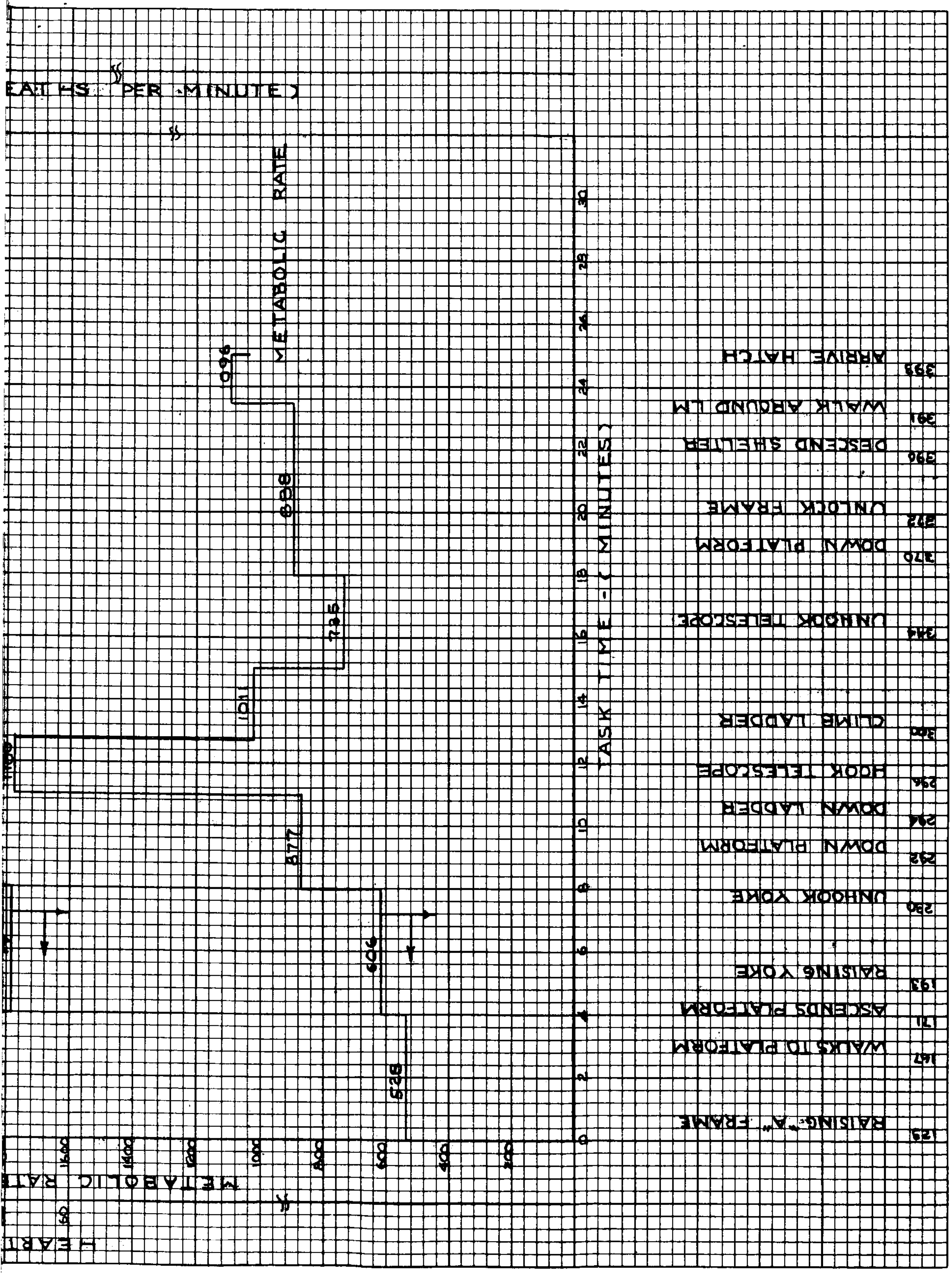


FIGURE B-12
METABOLIC DATA FOR OAP TASK
SUBJECT : B
POSITION : A
SUIT : A-4H-035
SUIT PRESSURE : 3.7 PSIG



RAISING "A" FRAME
WALKS TO PLATFORM
ASCENDS PLATFORM
RAISING YOKE
UNHOOK YOKE
DOWN PLATFORM
DOWN LADDER
HOOK TELESCOPE
CLIMB LADDER
UNHOOK TELESCOPE
DOWN PLATFORM
UNLOCK FRAME
DESCEND SHELTER
WALK AROUND LM
ARRIVE HATCH
TASK TIME - (MINUTES)
METABOLIC RATE
528
606
877
1011
735
838
960

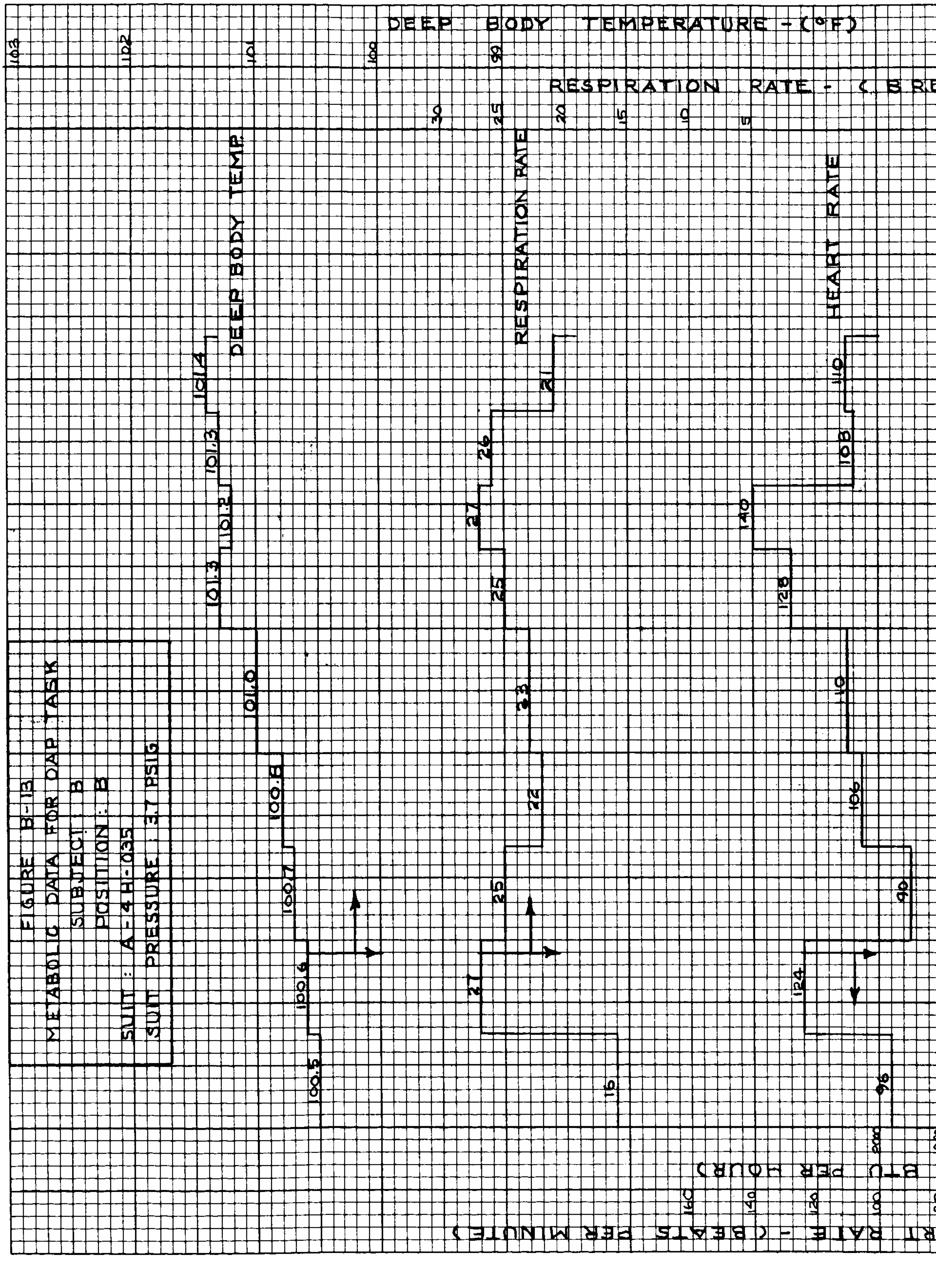
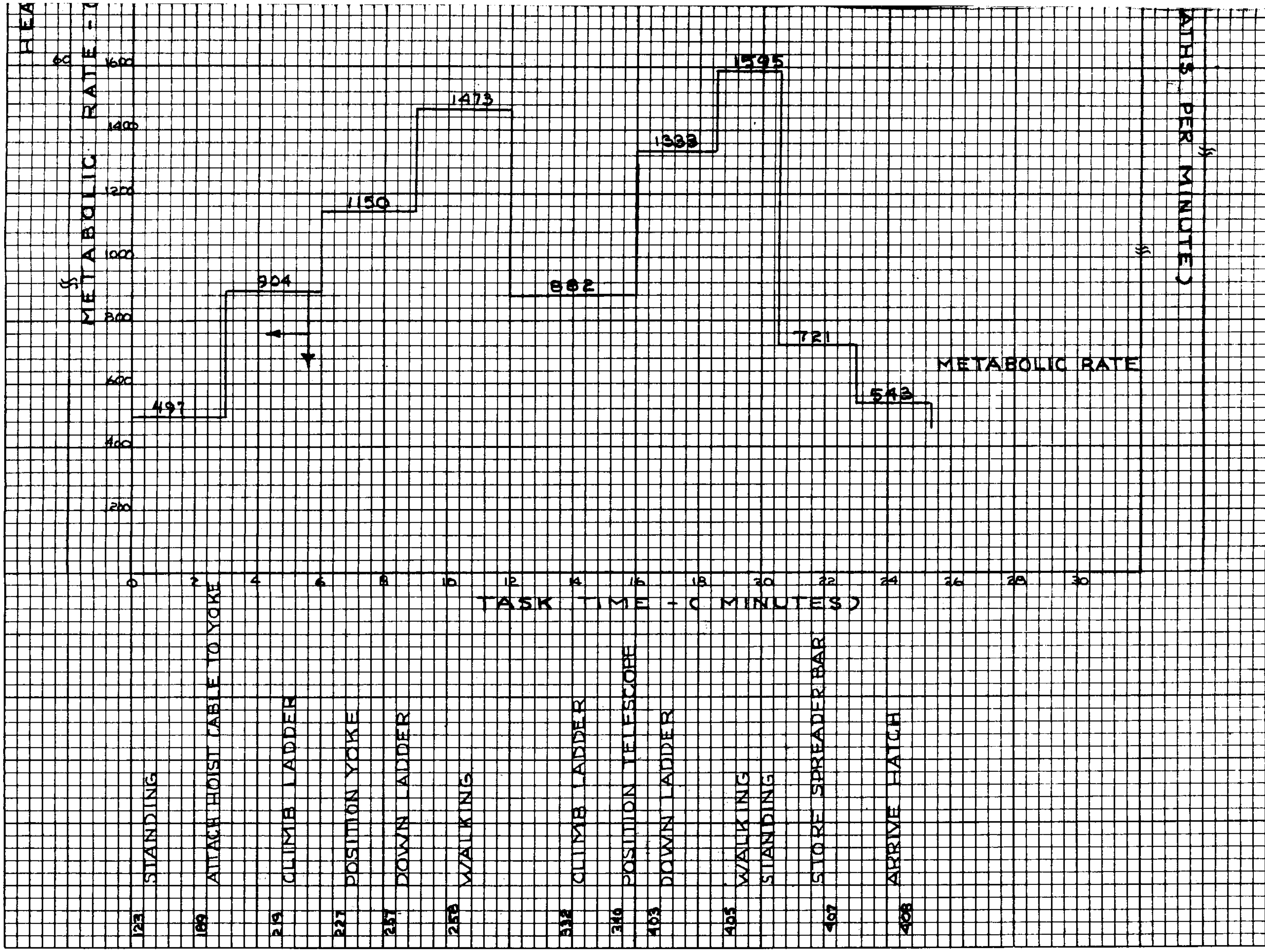


FIGURE B-13
METABOLIC DATA FOR OAP TASK
SUBJECT: B
POSITION: B
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG


HEA
METABOLIC RATE
ATHS PER MINUTE)
60
1600
1400
1200
1000
800
600
400
200
497
904
1150
1473
882
1333
1595
721
543
METABOLIC RATE
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TASK TIME - (MINUTES)
123 STANDING
189 ATTACH HOIST CABLE TO YOKE
219 CLIMB LADDER
227 POSITION YOKE
257 DOWN LADDER
258 WALKING
332 CLIMB LADDER
346 POSITION TELESCOPE
403 DOWN LADDER
405 WALKING
STANDING
407 STORE SPREADER BAR
408 ARRIVE HATCH

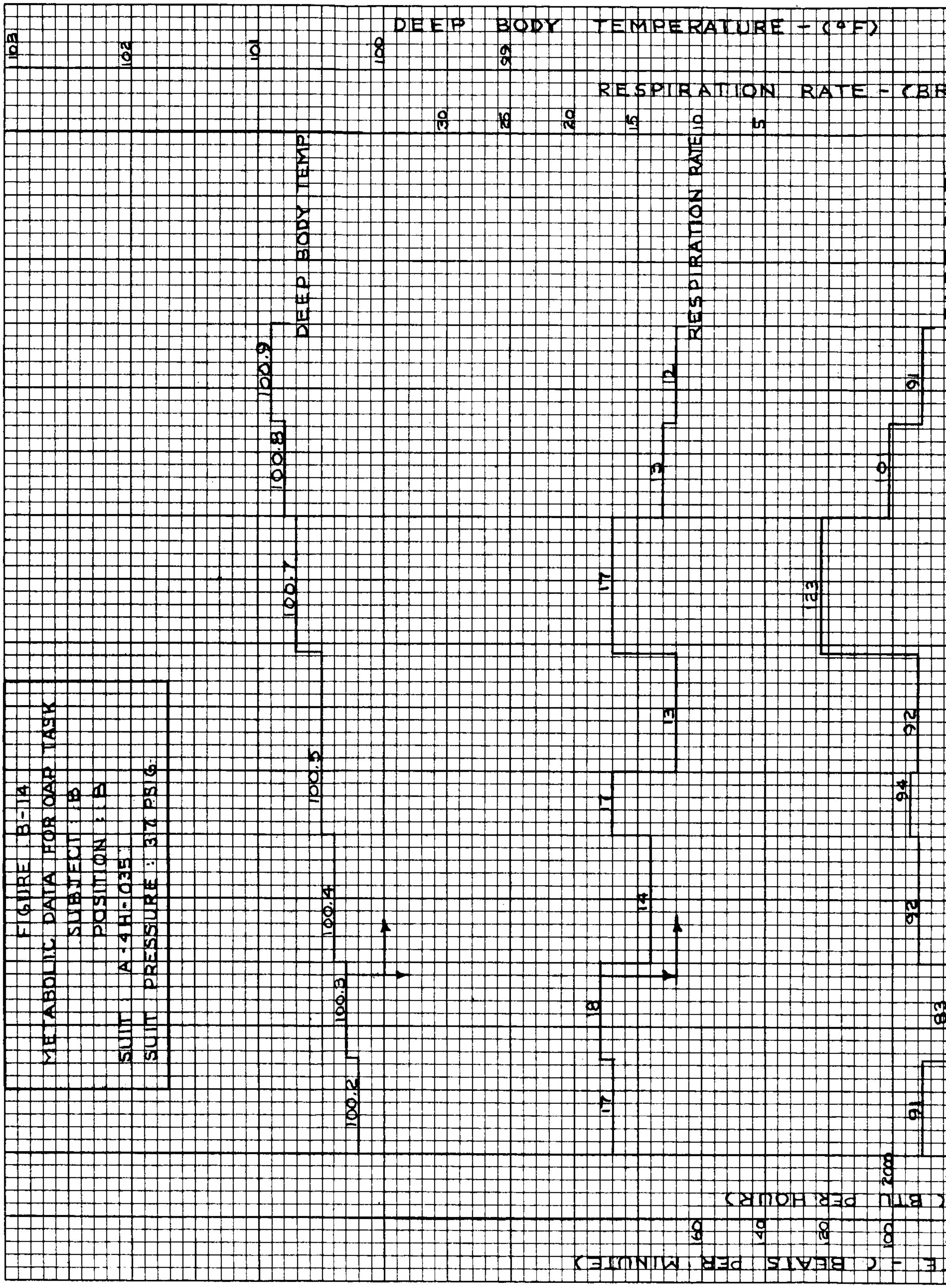
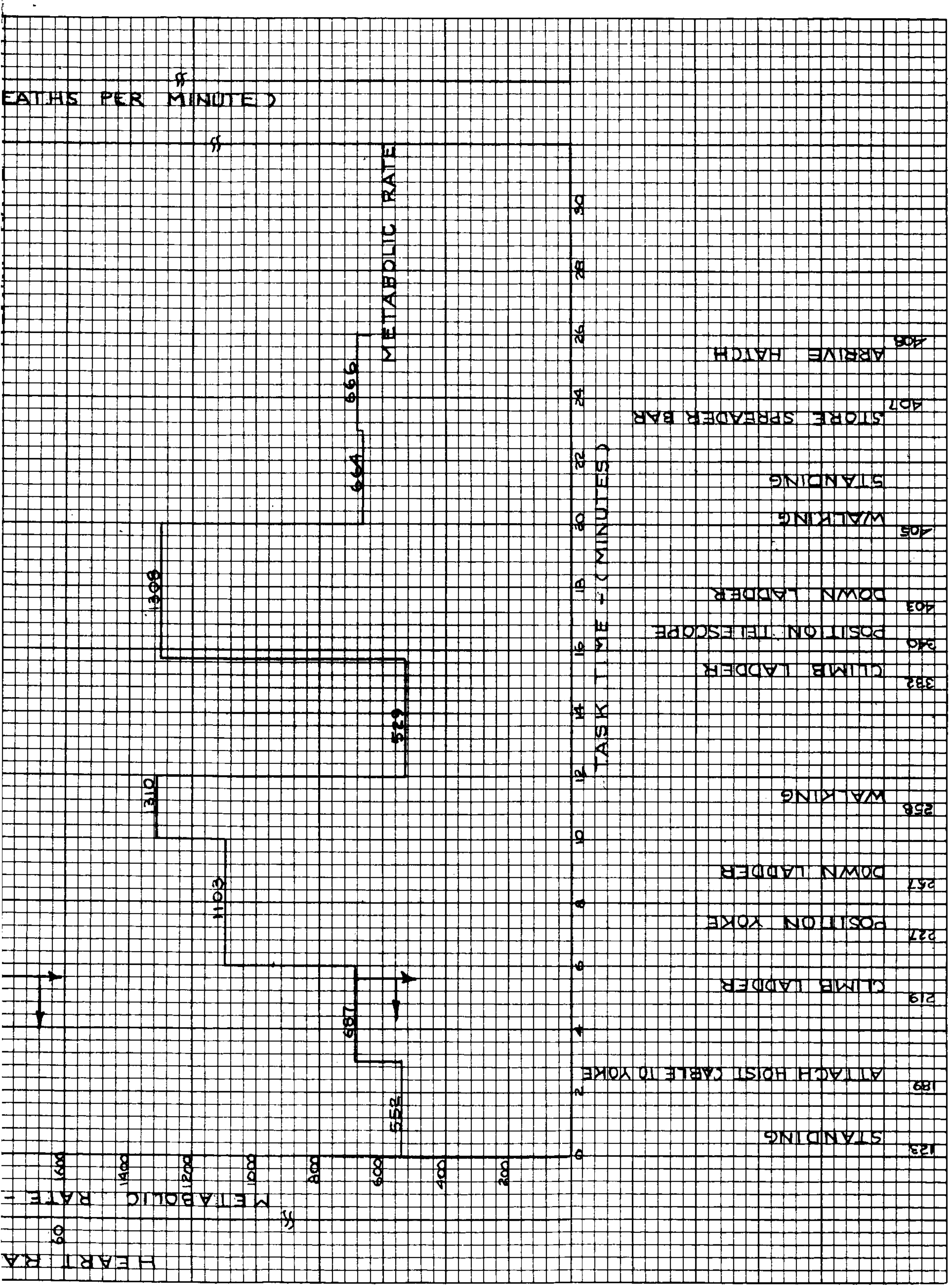


FIGURE B-14
METABOLIC DATA FOR OAP TASK
SUBJECT: B
POSITION: B
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG


EATHS PER MINUTE)
METABOLIC RATE
TASK TIME - (MINUTES)
METABOLIC RATE -
HEART RA
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
200
400
600
800
1000
1200
1400
1600
60
552
687
1103
1310
529
1308
664
666
153 STANDING
189 ATTACH HOIST CABLE TO YOKE
219 CLIMB LADDER
227 POSITION YOKE
257 DOWN LADDER
258 WALKING
332 CLIMB LADDER
340 POSITION TELESCOPE
403 DOWN LADDER
405 WALKING
STANDING
407 STORE SPREADER BAR
408 ARRIVE HATCH

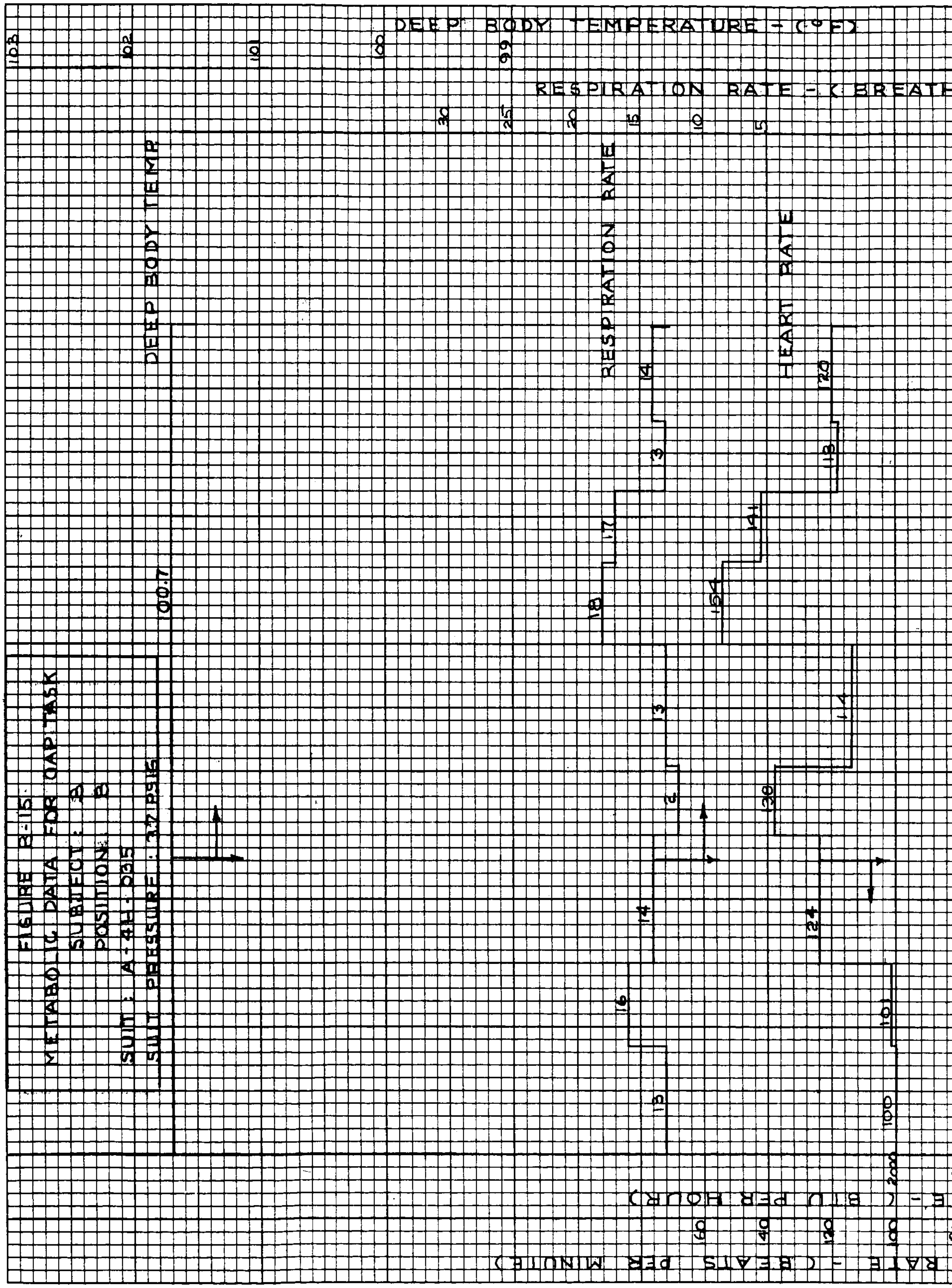
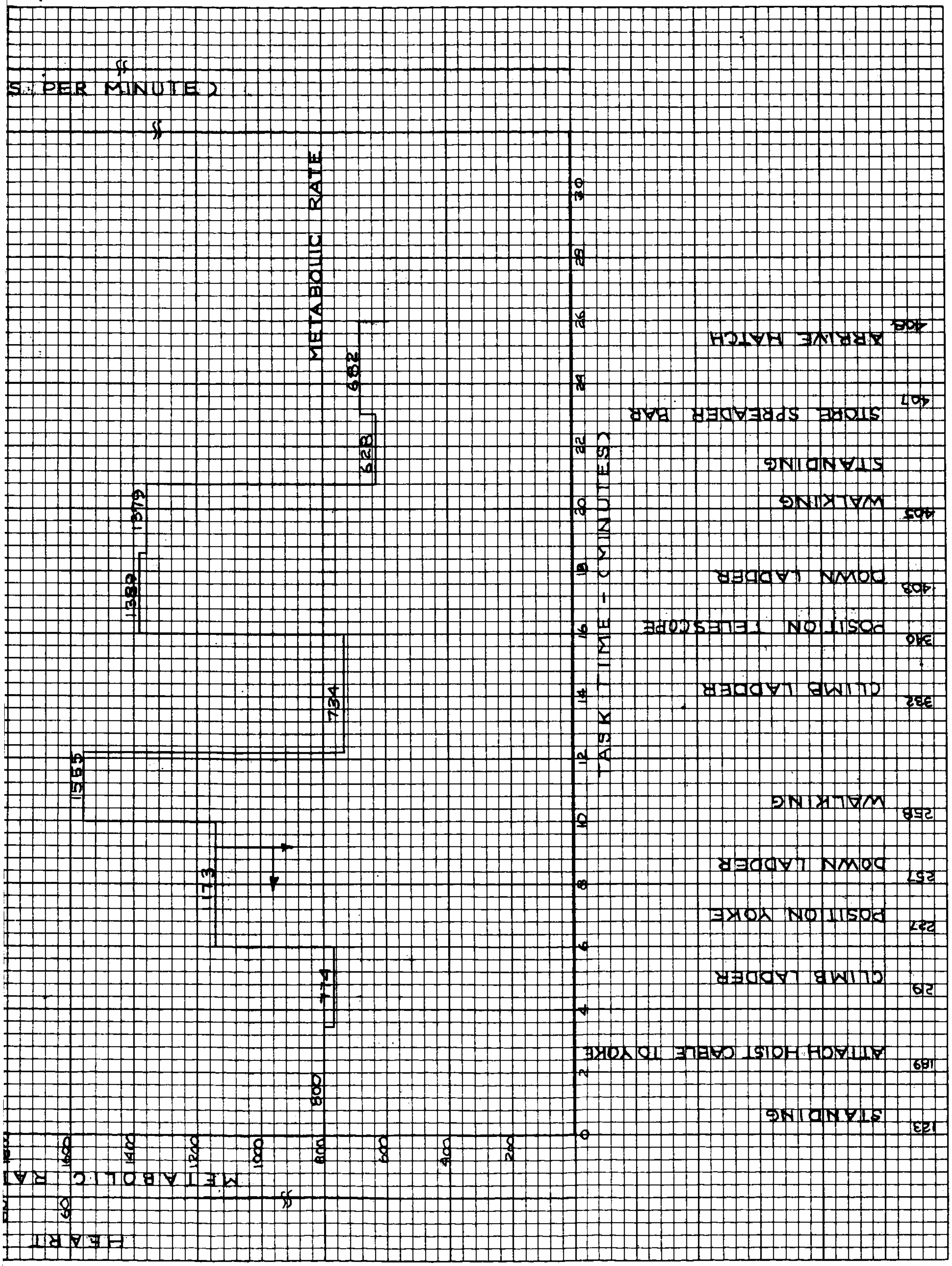


FIGURE B-15
METABOLIC DATA FOR OAP TASK
SUBJECT: B
POSITION: B
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG


S PER MINUTE)
METABOLIC RATE
TASK TIME - (MINUTES)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
800
774
173
1565
734
1389
1379
628
682
123 STANDING
169 ATTACH HOIST CABLE TO YOKE
29 CLIMB LADDER
227 POSITION YOKE
257 DOWN LADDER
258 WALKING
332 CLIMB LADDER
340 POSITION TELESCOPE
403 DOWN LADDER
405 WALKING
STANDING
407 STORE SPREADER BAR
408 ARRIVE HATCH
200
400
600
800
1000
1200
1400
1600
METABOLIC RA
60
HEART

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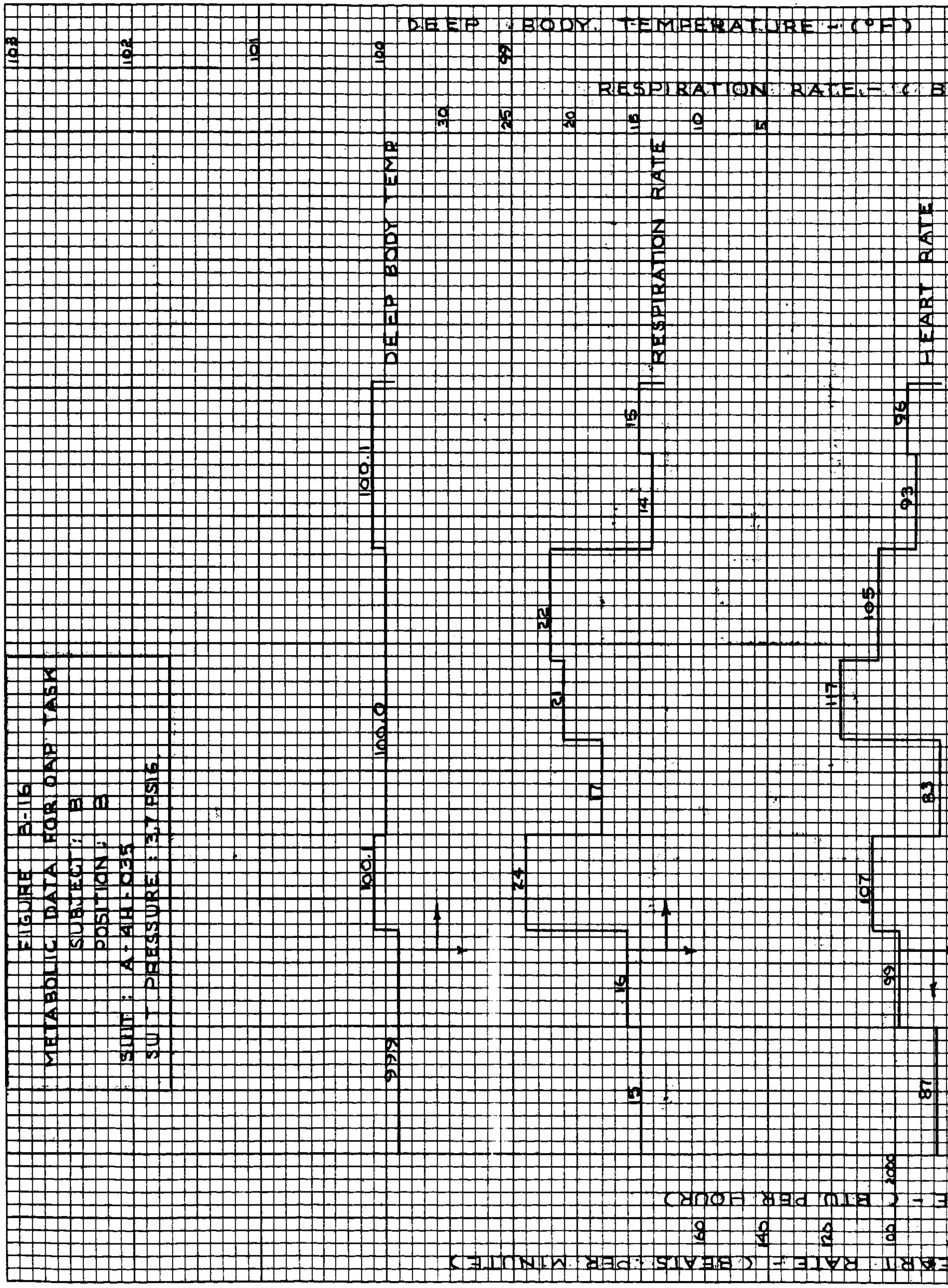

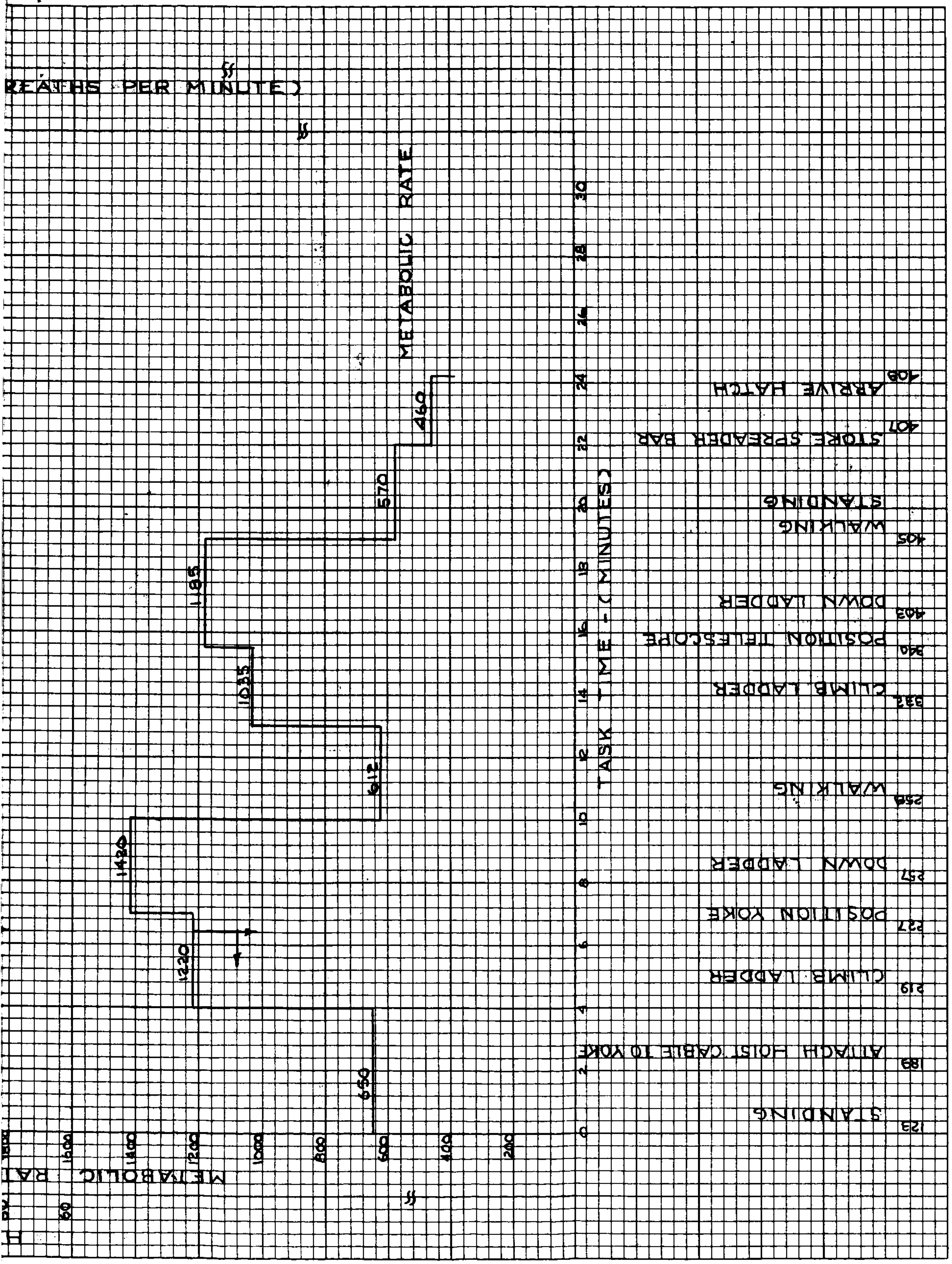
METABOLIC RATE
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH
650
1220
1420
612
1035
1185
570
460

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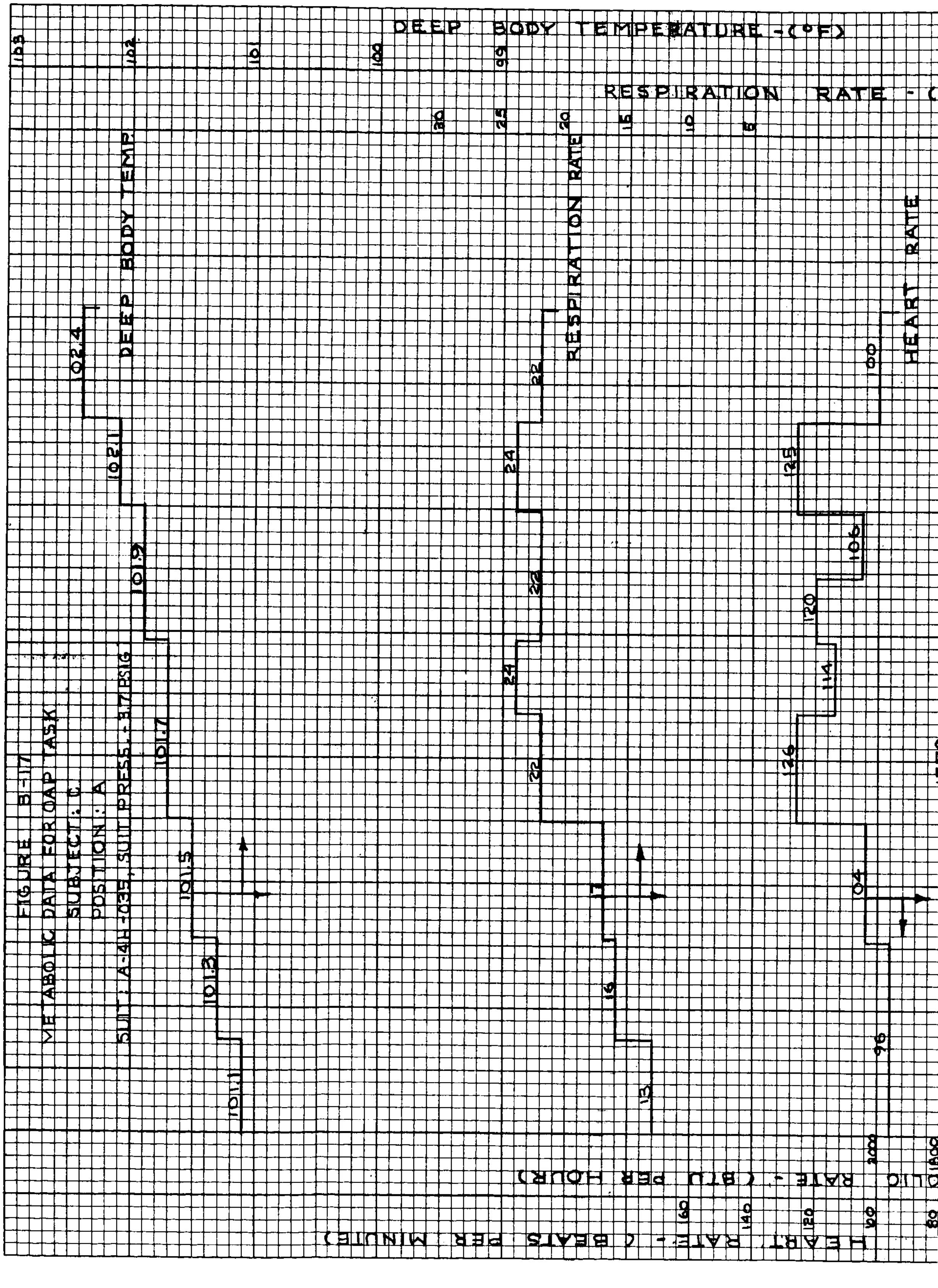



(BREATHS PER MINUTE)
METABOLIC RATE
TASK TIME - (MINUTES)
724
924
767
1231
1053
970
1211
1171
123 RAISING "A" FRAME
167 WALKS TO PLATFORM
171 ASCENDS PLATFORM
193 RAISING YOKE
230 UNHOOK YOKE
292 DOWN PLATFORM
294 DOWN LADDER
296 HOOK TELESCOPE
300 CLIMB LADDER
344 UNHOOK TELESCOPE
370 DOWN PLATFORM
372 UNLOCK FRAME
390 DESCEND SHELTER
391 WALK AROUND LM
393 ARRIVE HATCH

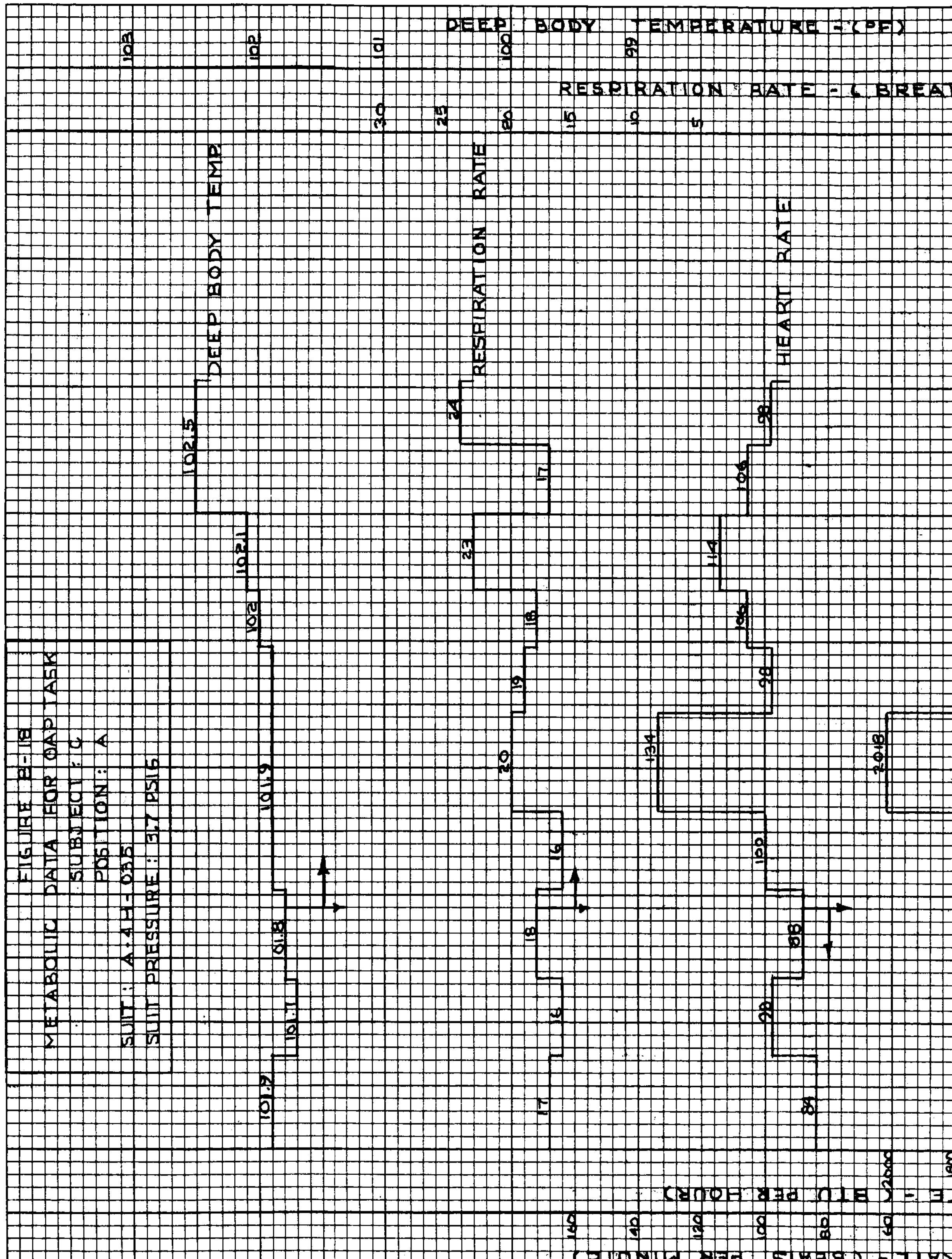
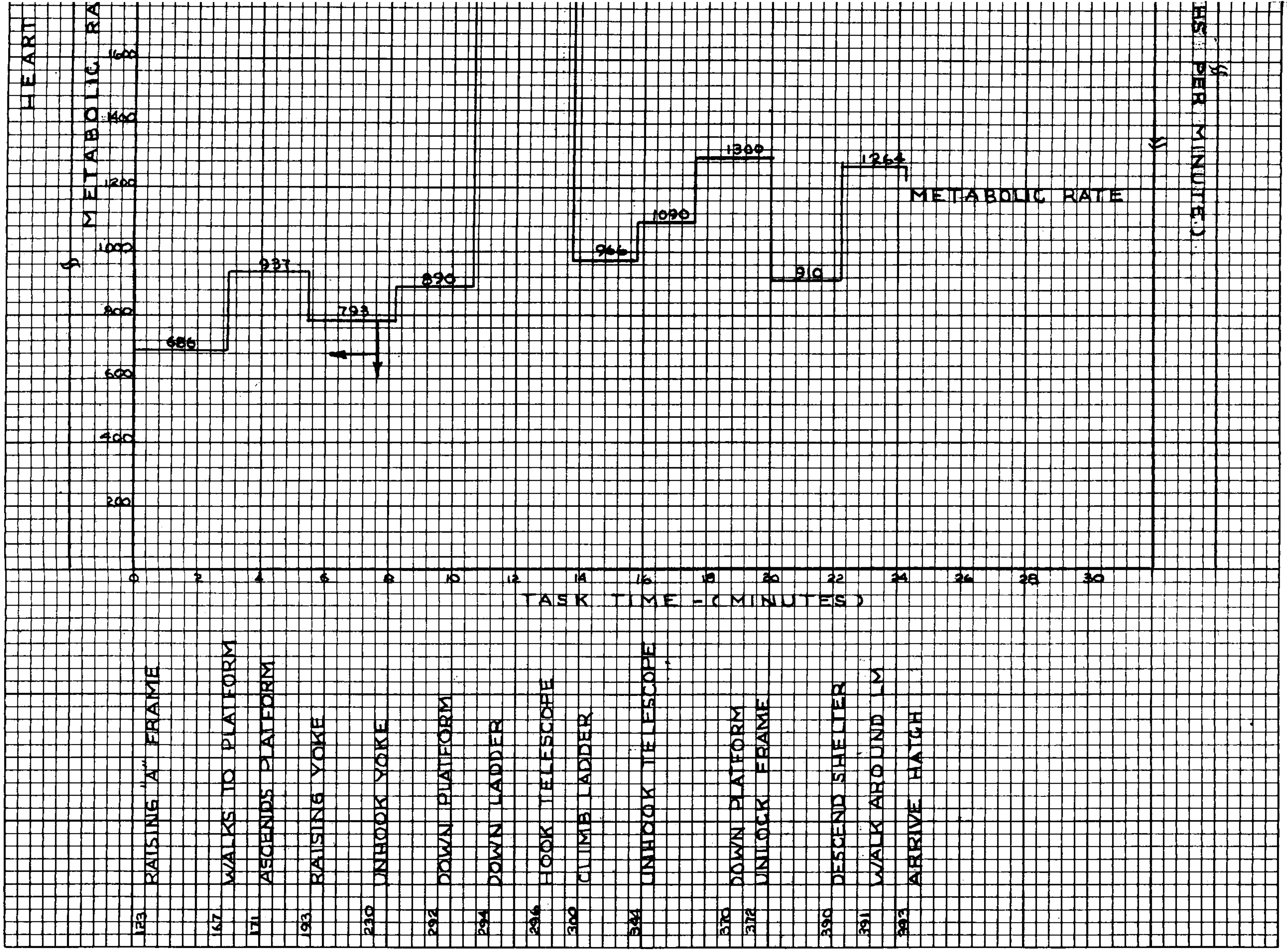


FIGURE B-18
METABOLIC DATA FOR OAP TASK
SUBJECT: G
POSITION: A
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG
DEEP BODY TEMPERATURE - (°F)
RESPIRATION RATE - (BREAT
DEEP BODY TEMP
RESPIRATION RATE
HEART RATE
(BEATS PER MINUTE)
(BTU PER HOUR)


HEART
METABOLIC RA
HS PER MINUTE)
METABOLIC RATE
1600
1400
1200
1000
800
600
400
200
686
937
793
890
966
1090
1300
910
1264
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
TASK TIME - (MINUTES)
123 RAISING "A" FRAME
167 WALKS TO PLATFORM
171 ASCENDS PLATFORM
193 RAISING YOKE
230 UNHOOK YOKE
292 DOWN PLATFORM
294 DOWN LADDER
296 HOOK TELESCOPE
300 CLIMB LADDER
344 UNHOOK TELESCOPE
370 DOWN PLATFORM
372 UNLOCK FRAME
390 DESCEND SHELTER
391 WALK AROUND LM
393 ARRIVE HATCH

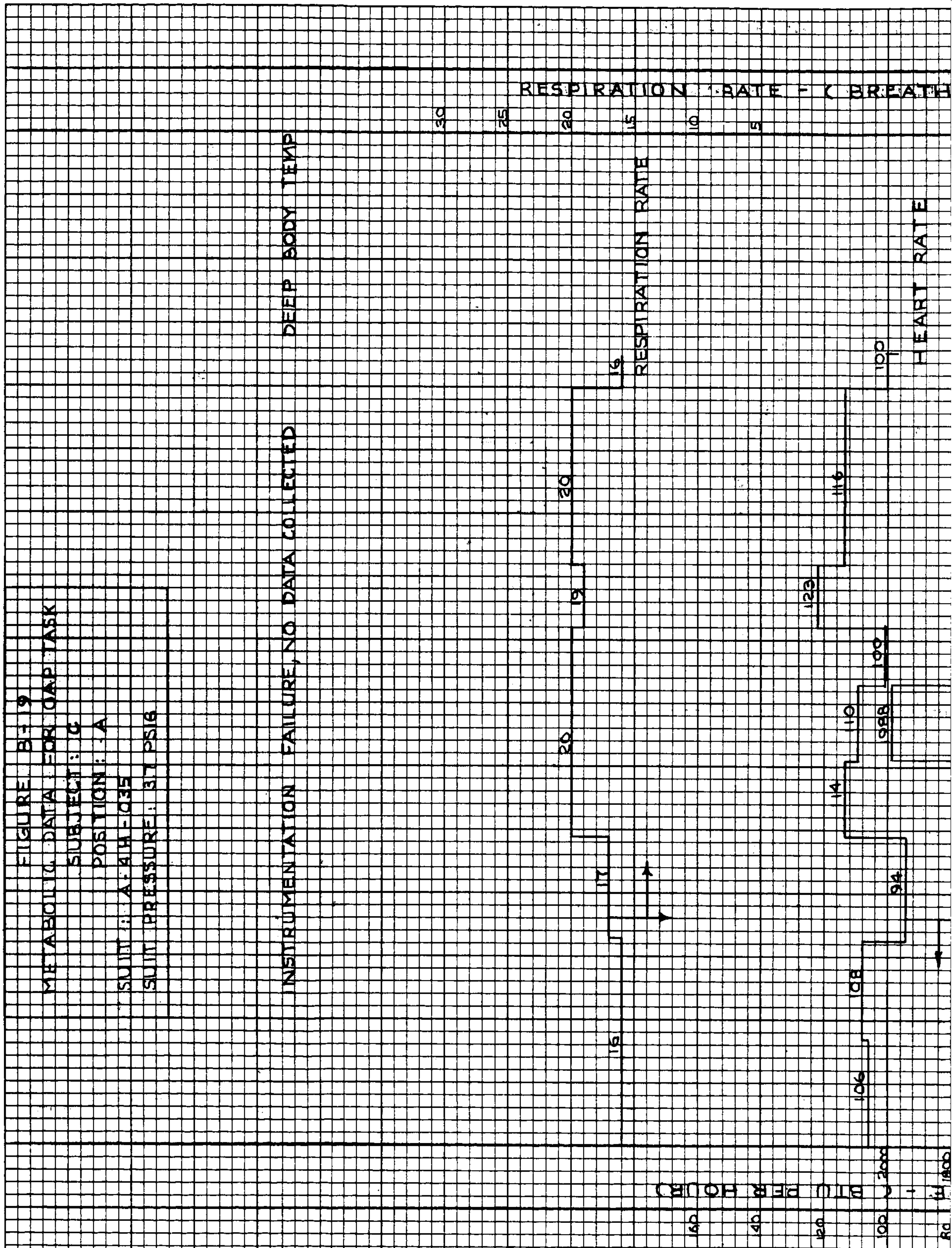
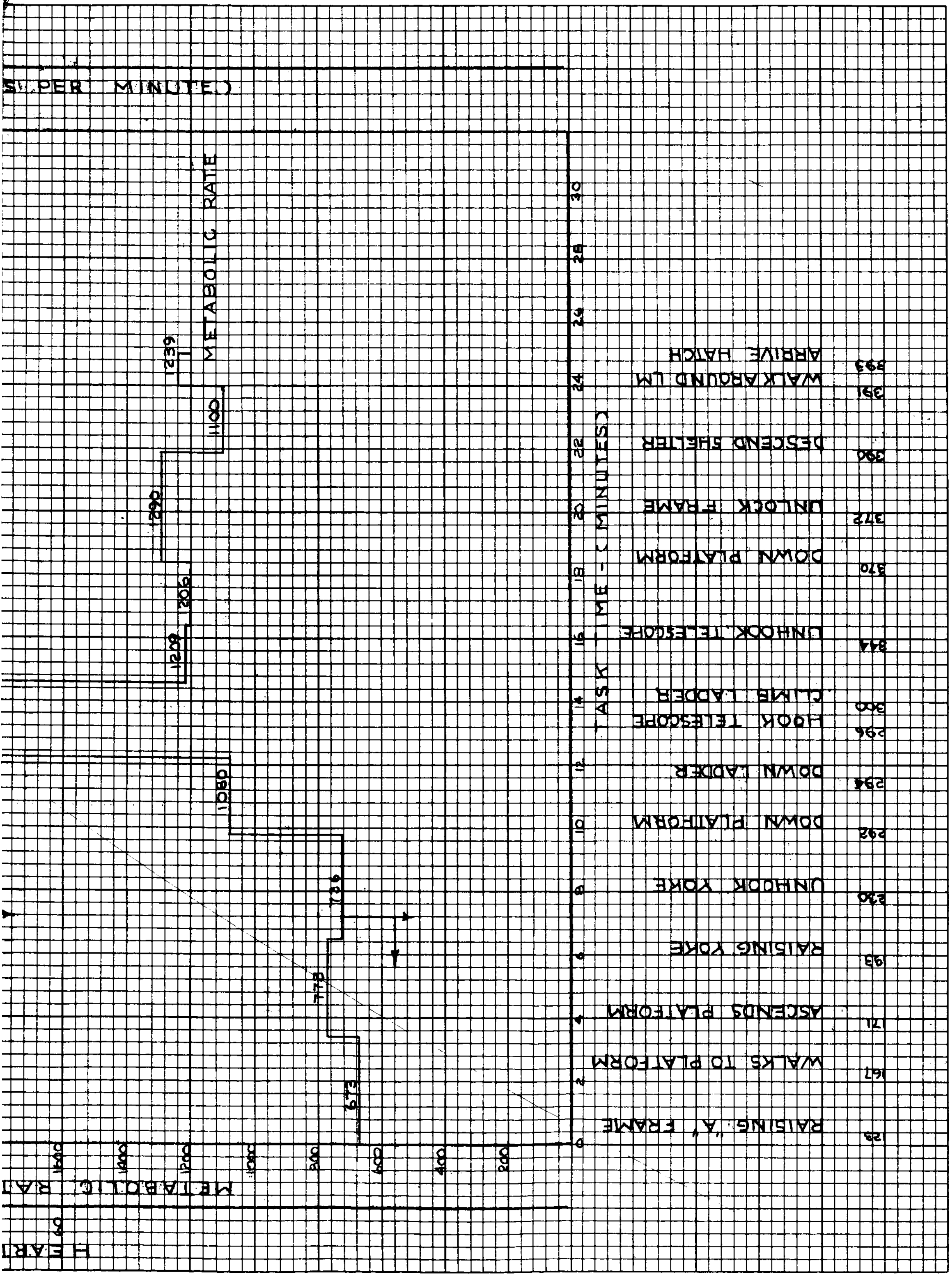


FIGURE B-9
METABOLIC DATA - OR GAP TASK
SUBJECT: C
POSITION: A
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG
INSTRUMENTATION FAILURE, NO DATA COLLECTED
DEEP BODY TEMP
RESPIRATION RATE
HEART RATE
RESPIRATION RATE - (BREATH
BTU PER HOUR)
RATE - (BEATS PER MINUTE)
30
25
20
15
10
5
16
20
19
20
17
19
100
116
123
100
110
998
114
94
108
106
2000
1800
160
140
120
100


METABOLIC RATE
TASK TIME - (MINUTES)
RAISING "A" FRAME
WALKS TO PLATFORM
ASCENDS PLATFORM
RAISING YOKE
UNHOOK YOKE
DOWN PLATFORM
DOWN LADDER
HOOK TELESCOPE
CLIMB LADDER
UNHOOK TELESCOPE
DOWN PLATFORM
UNLOCK FRAME
DESCEND SHELTER
WALK AROUND LM
ARRIVE HATCH
673
778
736
1080
1209
1206
1290
1100
1239
(...S PER MINUTE)
METABOLIC RA...
HEART...

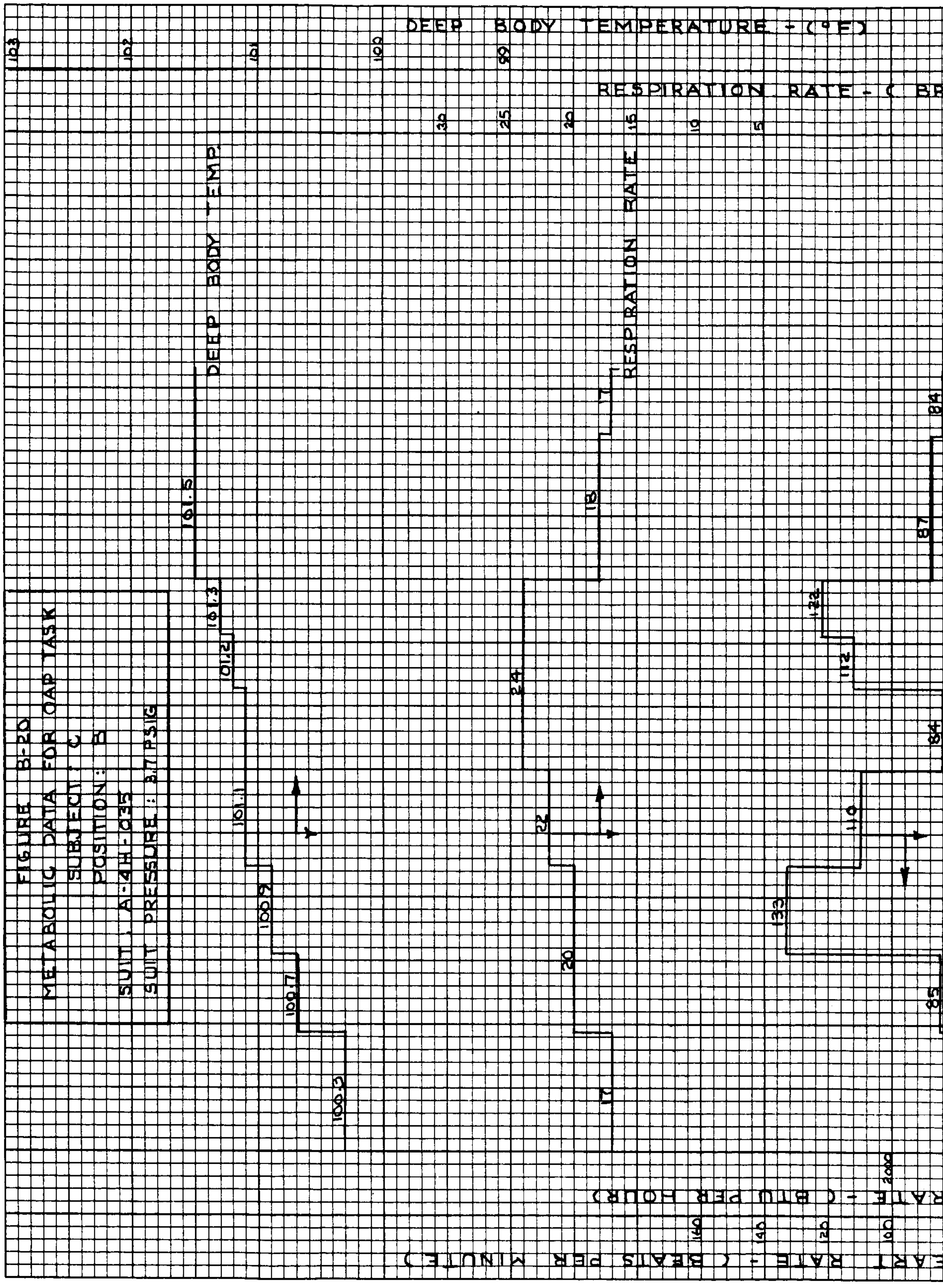
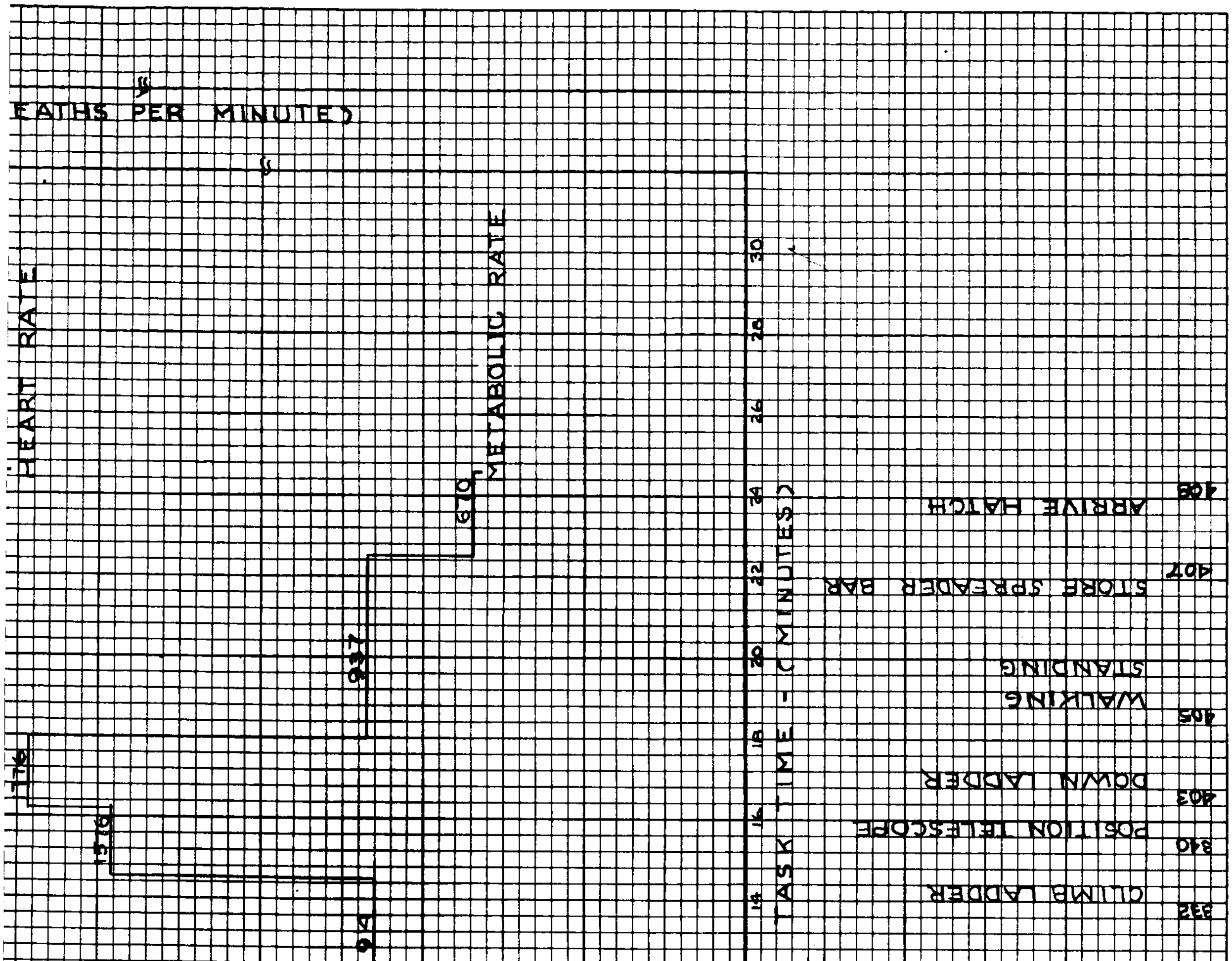


FIGURE B-20
METABOLIC DATA FOR OAP TASK
SUBJECT: C
POSITION: B
SUIT: A-4H-035
SUIT PRESSURE: 3.7 PSIG


EATHS PER MINUTE)
HEART RATE
METABOLIC RATE
TASK TIME (MINUTES)
METABOLIC
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH
654
1128
1877
1707
94
1516
937
670

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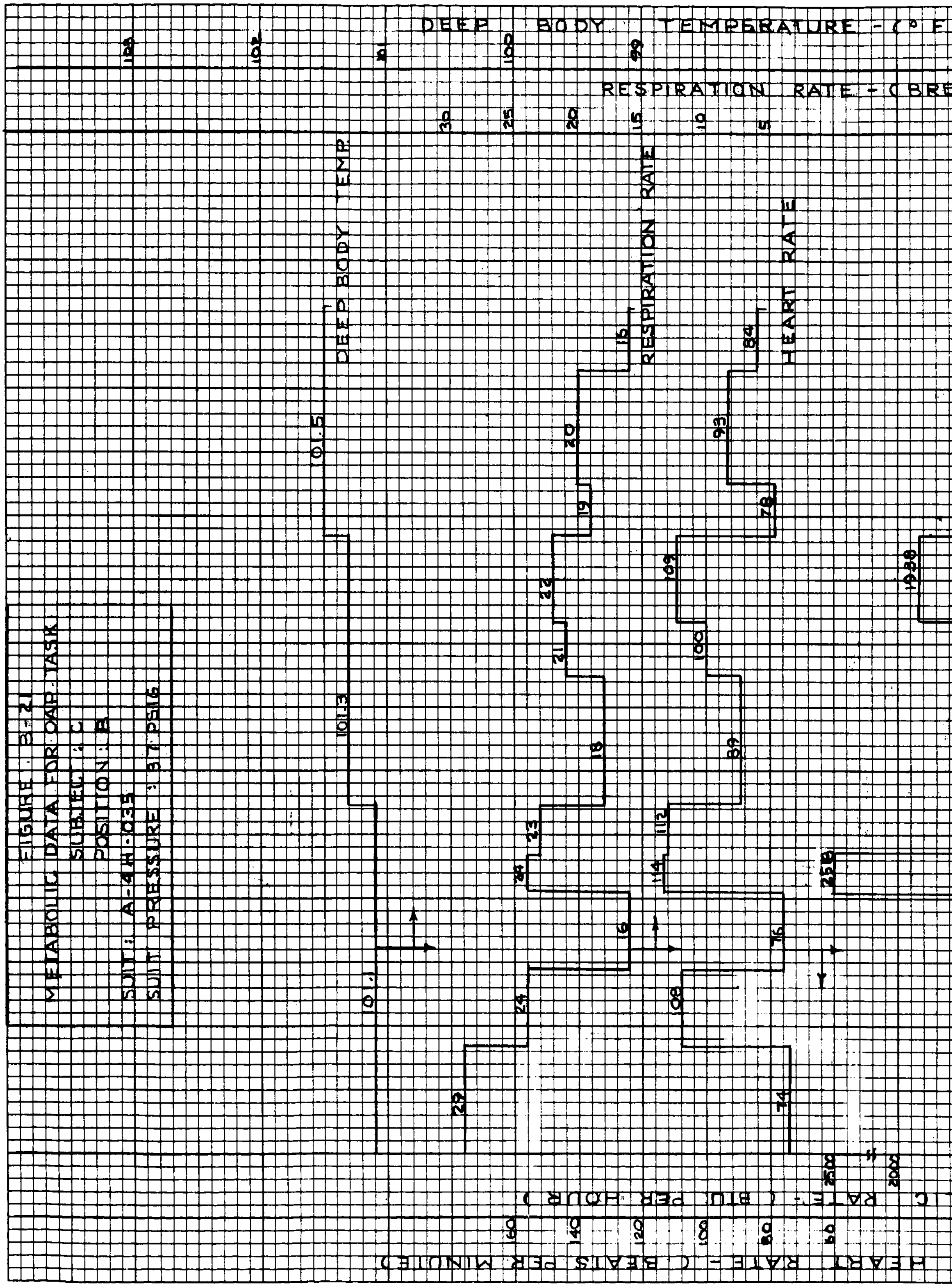

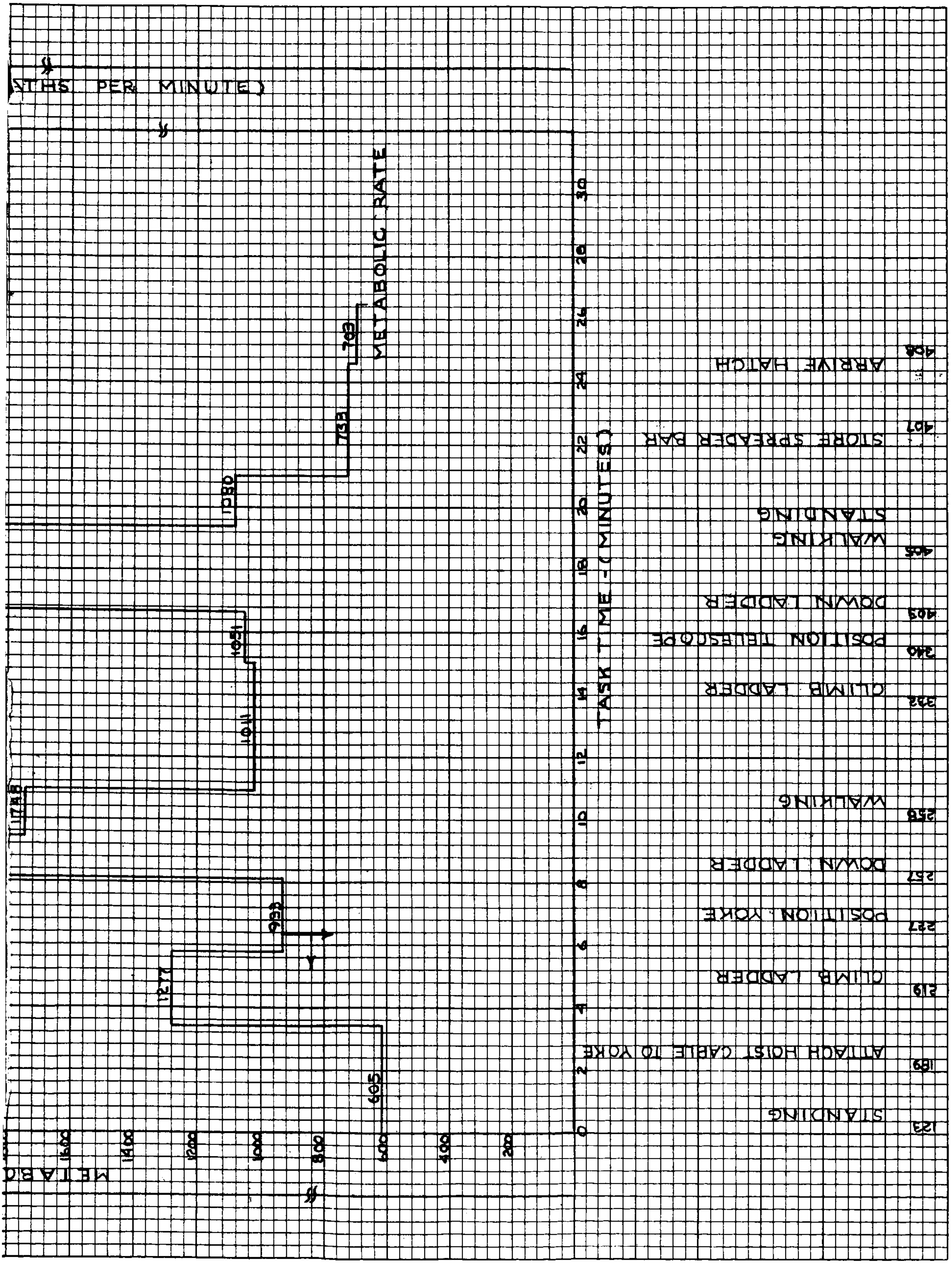
METABOLIC RATE
TASK TIME - (MINUTES)
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH
605
1271
933
1748
1011
1051
1030
733
703

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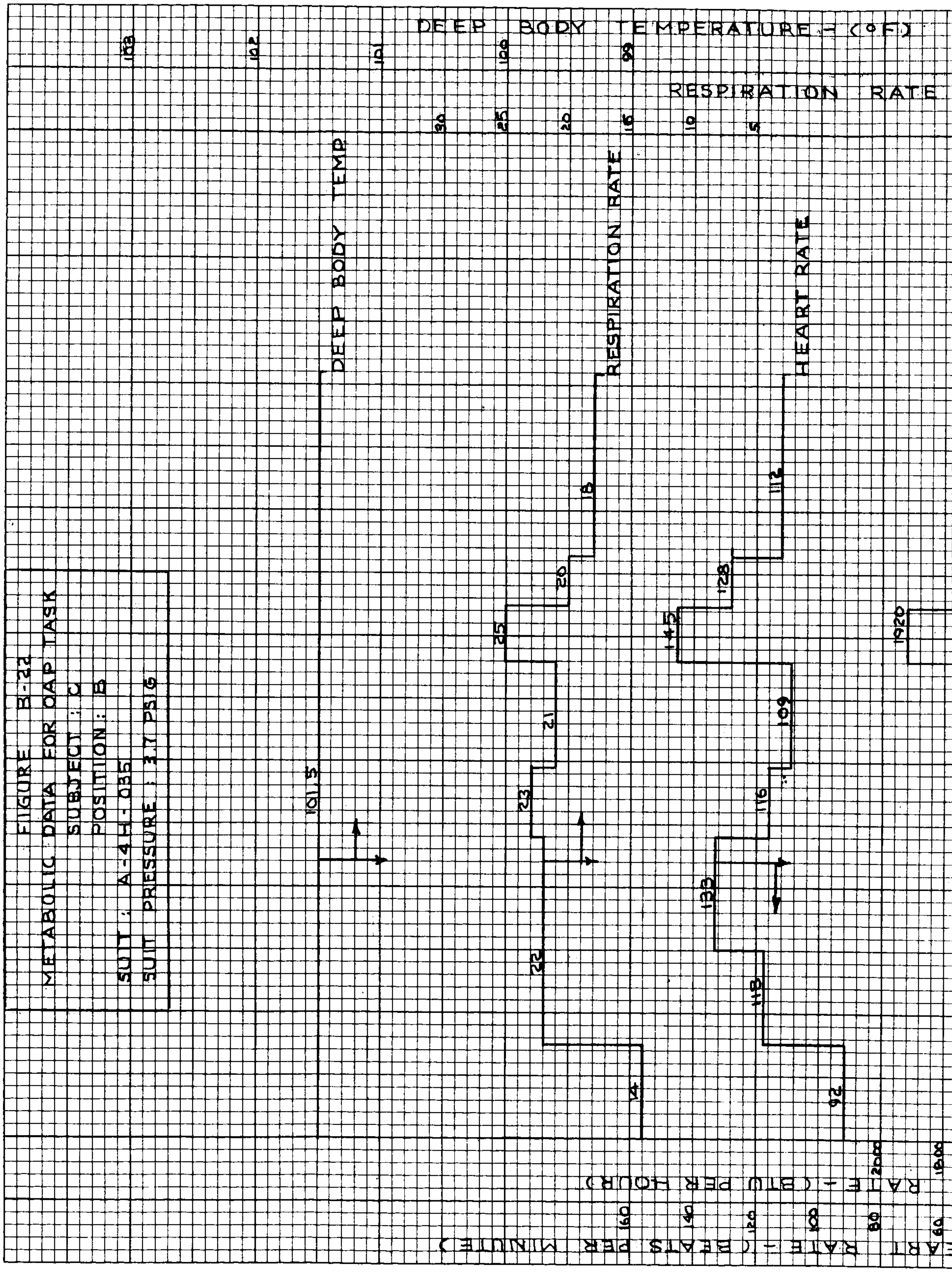
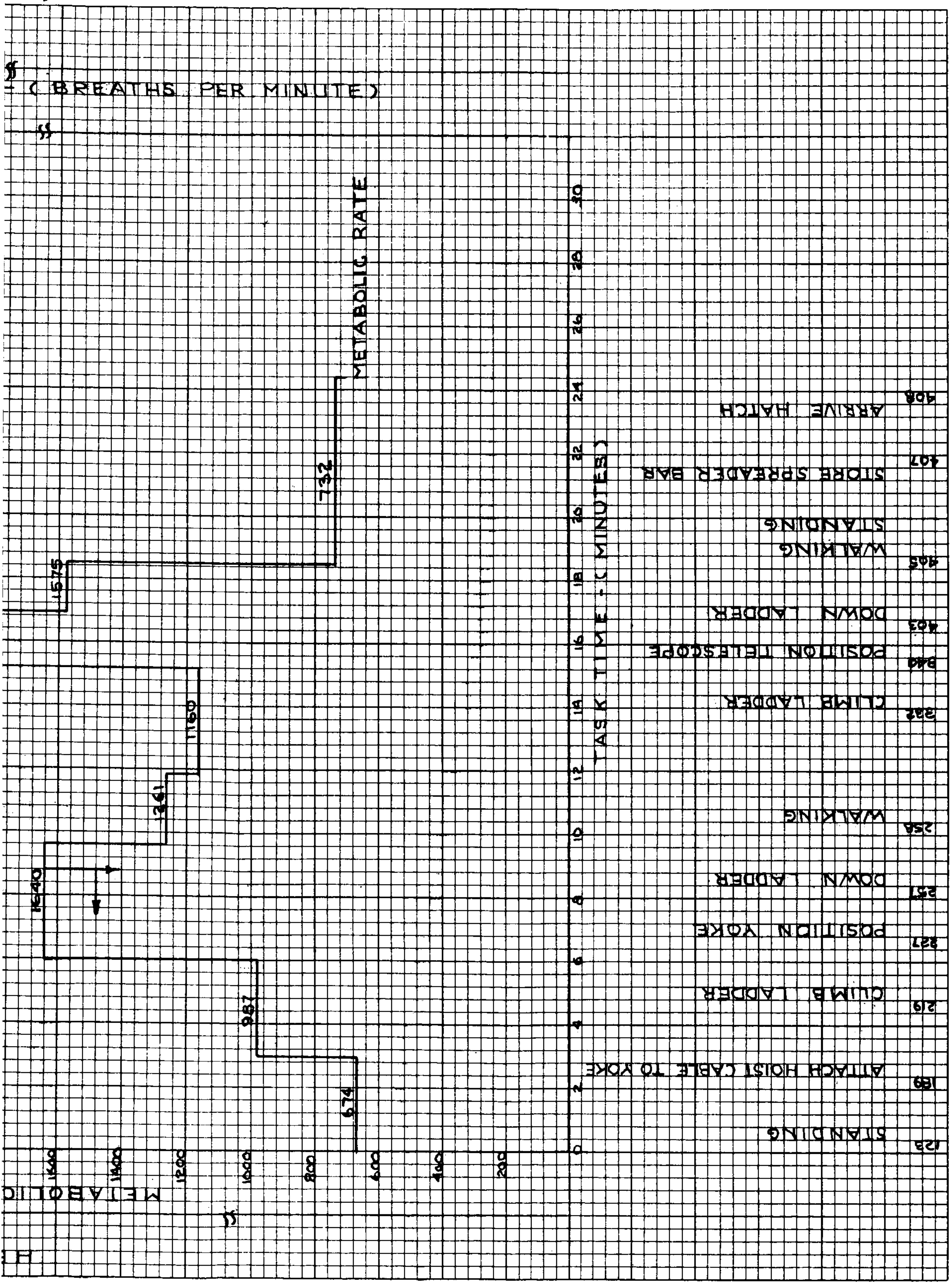


FIGURE B-22
METABOLIC DATA FOR OAP TASK
SUBJECT : C
POSITION : B
SUIT : A-4H-035
SUIT PRESSURE : 3.7 PSIG


(BREATHS PER MINUTE)
METABOLIC RATE
TASK TIME - (MINUTES)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
200
400
600
800
1000
1200
1400
1600
674
987
1640
961
1160
1575
732
STANDING
ATTACH HOIST CABLE TO YOKE
CLIMB LADDER
POSITION YOKE
DOWN LADDER
WALKING
CLIMB LADDER
POSITION TELESCOPE
DOWN LADDER
WALKING
STANDING
STORE SPREADER BAR
ARRIVE HATCH